CHEMISTRY

APPLIED TO

ARTS AND MANUFACTURES.

VOL. IV.

John Steele

CHEMISTRY

APPLIED TO

ARTS

AND

MANUFACTURES.

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CHEMISTRY

APPLIED TO THE ARTS.

CHAPTER IX.

On the Combinations of the Sulphuric Acid.

OF all the acids, the sulphuric furnishes the greatest number of saline combinations applicable to the arts; and as most of these salts are presented to the hand of industry ready formed by nature, it seems probable that to this cause is owing their extensive, and very general adoption for such purposes.

These salts possess peculiar characters, by which they are easily recognized.

They are insoluble in alcohol, and when

dissolved in water are precipitated in small crystals, by the addition of this liquor.

Heat does not decompose the alkaline sulphates; and in order to separate the acid from the metallic and earthy sulphates, long continued and intense heat is requisite.

A watery solution of barytes decomposes all the sulphates, forming sulphates of barytes, which are precipitated.

The sulphates, in general, have an astringent or bitter taste.

One character, which appears to be peculiar to all the combinations of sulphuric acid, is the deposition which takes place in their solutions, of a portion of sulphate deprived of the water of crystallization, in cases where the liquid is insufficient to furnish it to the whole mass; thus, for example, in evaporating the water taken from the salt pits of La Meurthe, an abundant precipitation of sulphate of soda takes place, entirely destitute of the water of crystallization, while another portion of this sulphate remains in solution, and crystallizes on becoming cold.

Sulphate of lime, deprived of its water of crystallization, has been found in Sweden, the

Tyrol, and in different parts of the globe. It was first discovered in this state by M. Haüy, and described by Fleuriau in 1798, in the Journal de Physique, and Bournon and Chenevix in the Journal des Mines. M. Vauquelin has given an accurate analysis of this substance.

It is sufficiently well known, that when a solution of sulphate of iron, during the process of evaporation, is concentrated to 40 or 42° of Beaume's hygrometer, it becomes turbid and cloudy, throwing down a very hard whitish precipitate, which it is difficult to detach from the bottom of the vessels; and this precipitate is found on examination to be sulphate of iron, deprived of its water of crystallization, and which again becomes green on being redissolved.

It appears that when solutions of sulphates approach such a point, that there is not a sufficient quantity of water to supply what may be necessary for the formation of crystals, that a portion of the salt is precipitated in a dry state, in consequence of which the solution indicates from 4 to 6° less on the hygrometer than before.

Another characteristic of the sulphates is, that almost the whole of them part with their water of crystallization on exposure to a very moderate heat, but afterwards become extremely difficult of fusion, and only yield their acid to intense and long continued heat, so that these salts admit of two different kinds of fusion. The first we shall term *aqueous*, as it simply consists in the solution of salt in the water of crystallization by the aid of a gentle heat; and the other *igneous*, because it is produced by very intense heat applied to the dried sulphate.

SECTION I.

On the Combinations of the Sulphuric Acid with Potash.

The most common product of this combination is the sulphate of pot-ash, known in commerce by the name of *vitriolated tartar, arcanum duplicatum, sal de duobus*, and *vitriol of potas*

This salt is only employed in medicine, and apothecaries prepare it by the direct combina-

tion of the acid and alkali. But that which is usually found in the druggists' shops is procured from the manufactures of aqua fortis, and is the residue of the decomposition of the nitrates of potash by sulphuric acid.

This sulphate, which is found in a congealed mass in the cucurbit after distillation, only requires to be dissolved in water and sufficiently concentrated in order to assume the form of crystals.

It is sometimes confined during the process of cooling so as to assume the shape of square lozenges, or tablets, from four to six lines in thickness; and it is under this form that it is most commonly met with in the shops.

This salt has a penetrating taste without being very disagreeable, it readily dissolves in the mouth, and cracks under the teeth.

Its crystals are in the form of hexahedral prisms, terminating in hexahedral pyramids. These prisms are shorter in proportion to the greater concentration of the solution.

This sulphate decrepitates on hot coals, but fuses when the heat is augmented, and is volatilized without decomposition. When exposed to the action of the blow pipe, it decre-

pitates with considerable noise, melts, and flows over the coals which serve to support it, leaving a reddish or yellow residuum, which diffuses the odour of sulphurated hydrogen gas on the addition of an acid. Hence it is evident, that in this case the acid is decomposed.

The saturated sulphate of potash is not changed by exposure to the air.

Its constituent principles are combined in the following proportions :

Bergman.	Kirwan.	Thomson.
40	45,2	31,0 acid
52	54,S	67,6 potash
S	0,0	1,4 water.

M. Berthollet found that 49,33 of pure acid was necessary to saturate 100 parts of pot-ash.

The specific weight of this sulphate is, according to

Brisson	and to	Hassenfratz.
2,298		2,4073

It is soluble in sixteen times its weight of

water at 60° of Fahrenheit. Boiling water dissolves between a fourth and a fifth of it.

This salt is decomposable by the salts of barytes, the nitrates and muriates of lime, and of strontian, and by all the metallic salts of which the base forms a salt insoluble with sulphuric acid.

The sulphate of potash is rarely found ready formed. However, when vegetables are impregnated with pyrites, as we have seen in trees buried beneath the surface of the earth, and sometimes in heaps of plants in a state of putrefaction, sulphuric acid is produced, during their decomposition, which combining with potash, one of the constituent principles of these substances forms sulphate of potash. Bowle affirms, he has observed in Spain, the sulphate of potash combined with different earths, and I myself have extracted it by analysis from the ashes of tobacco.

The younger Rouelle admits a second species of sulphate of potash with an excess of acid, which runs into long slender needle-shaped crystals, soluble in two parts of water, at 60° of Fahrenheit. But this preparation, which is not in general use, only holds an in-

termediate degree between the perfect salt and the first rude attempt, so to speak, towards its formation.

SECTION II.

On the Combinations of the Sulphuric Acid with Soda.

The sulphate of soda is of a bitter nauseous taste, and readily dissolves in the mouth.

It crystallizes in octahedral prisms, of which the two pyramids are truncated near their base. The most usual form is, however, flattened hexangular prisms, terminated by dihedral summits.

It boils upon heated coals, without swelling, parts with its water of crystallization, and falls down into a white opaque powder, which is difficult of fusion, and volatilizes when exposed to a violent heat without decomposition.

The two different kinds of fusion already mentioned are very evident in this salt. The first occurs when it is exposed to a gentle heat, in which case, the great quantity of water contained in it dissolves the sulphate, and the fu-

sion continues till it is wholly dissipated; the second is produced, when the sulphate is rapidly deprived of its water of crystallization by being subjected to a violent degree of heat.

When exposed on charcoal to the action of the blowpipe, it is decomposed in the same manner, as when fused in a furnace, and in contact with charcoal.

This sulphate, of which the recent crystals are transparent and of a beautiful lustre, effloresces on exposure to the air, diminishes one half in weight, becomes opaque, loses its consistence, and falls down into a white saline powder.

Three parts of water dissolve at 60°, of Fahrenheit, one of salt, and boiling water equal parts.

Its constituent principles are in the following proportions:

Bergman.	Kirwan.
27	23,52 acid,
15	18,45 alkali,
58	58,00 water.

When this salt had been long dried, Kirwan

found the proportion of the acid to the alkali in the relation of 56 to 44.

Its specific weight is to that of water as 2246 to 1000.

The sulphate of soda is found in great abundance in many places, particularly mixed with natron. The waters of the Mediterranean yield it in the proportion of nearly 155 parts of their own weight; it is also present in various mineral waters. Wherever natron is produced, this salt is likewise to be found; and when we reflect that sulphur is almost inseparable from soda, since when moistened, a strong odour of sulphurated hydrogen never fails to be produced; and further, that the ashes of some marine plants furnish a large quantity of this sulphate, we must cease to wonder at the simultaneous existence of these two salts in the same situations.

The sulphate of soda employed in commerce is procured

1. From sea-water, or that taken from salt pits.
2. From the ashes of *tamarix gallica.*
3. From the manufactures of spirit of salt, or muriatic acid.

1. The mother-waters of salt-pits are composed of earthy deliquescent muriates, sulphate of soda, and sulphate of magnesia, which two last we may readily procure by crystallization.

The salt-marshes in the vicinity of Narbonne have long furnished all the sulphate employed in the South of France; those of Touraine, of Jura, and of Mont Blanc also produce a considerable quantity.

2. As the *tamarix gallica* grows in great abundance on the shores of the Mediterranean, manufactures have been established in that quarter, in which the ashes are lixiviated in order to extract from them the sulphate of soda.

This plant is cut down about the end of summer, after which it is burnt, and the ashes lixiviated in the usual manner.

3. As the bolar earths decompose very imperfectly the muriate of soda, the sulphuric acid is employed in preference.

The residuum is a very dry mass of sulphate of soda which only requires to be dissolved in boiling water, and afterwards evaporated, in order to furnish a considerable quantity of sul-

phate of soda in crystals. This salt ought to be kept in well corked bottles, with the view of preventing its efflorescence. It is very generally employed in medicine as a purgative, as well as in smaller doses, largely diluted to answer different purposes.

This salt is sometimes prepared in imitation of Epsom salt, by the precipitation of the sulphate of soda from its solution in water by a reduction of temperature. For this purpose it is only necessary to increase the surface of the solution, and to agitate it at the commencement of the crystallization ; the crystals are then deposited on the bottom of the vessel, and assume a snowy appearance.

This salt is known in several parts of France, under the name of Epsom salt of Paris, because it has for a long time been prepared in that city.

The mother waters of salt pits, treated in the same manner, yield a mixture of sulphate of soda and magnesia ; sometimes even the sulphate of magnesia predominates.

The sulphate of soda is decomposed by potash, and by most of the substances which decompose the potash.

This salt is known in commerce, under the names of *Glauber's salt, sal mirabile, vitriol of soda,* &c.

SECTION III.

On the Combinations of the Sulphuric Acid with Lime.

This sulphate bears the name of *stone plaster* in the arts, and of selenite in ancient chemistry. After being calcined, and reduced to powder, it is termed *burned gypsum* or *plaster of Paris.*

The sulphate of lime is known by the following properties :

1. It possesses little hardness, and does not strike fire with steel.

2. It readily parts with its water of crystallization, and becomes opaque, pulverulent, friable, and of a dull white.

3. It is not easily soluble in water, and requires 500 parts of this fluid to hold it in solution.

4. It vitrifies on being placed in the focus of a burning lens, or when exposed to a degree of heat equal to that employed in the manu-

facture of porcelain, and is converted into a transparent glass. It readily melts when its laminæ are presented edge-ways to the action of the blowpipe. It is soluble with effervescence in borax.

5. The sulphate of lime, deprived of its water of crystallization, becomes heated on the application of water, and hardens in a very short time.

6. It does not effervesce with acids.

7. A portion of the lime is precipitated by the fixed alkalies.

8. Its specific weight to that of pure water is as 23 to 10.

Large masses, or extensive strata of sulphate of lime are found in numerous parts of our globe, and it is in this state, that it is termed *plaster stone,* quarry plaster, because it is by working these strata that we obtain this material, which is found so useful in the arts. When the sulphate of lime is found in large masses, it is for the most part not distinguished by any regular form; and the fragments detached from them exhibit only a rough grained fracture. But sometimes also, they are of a laminated texture, and semi-transparent, and

in this last case they exhibit a confused mixture of ill defined crystals.

Sometimes it assumes the form of very slender filaments forming strata of different degrees of thickness, and in this state it has obtained the name of *striated gypsum*. Many beautiful specimens of it, which may be seen in our cabinets, were imported from China, previous to its discovery in France, in several districts of which it is now known to exist. The city of Puy-en-Velay, in the department of the Upper Loire, is built on a bed of this stone, and I myself have found it in great abundance near Bédarieux, in the department of l'Hérault; it is also found at Bérzele-la-ville, near Mâcon.

The waters which flow over strata of gypsum, carry off, and dissolve a small portion of this salt, which they let fall on the soil, or on the rocks in their course. This deposition is termed *fossile flour*, when the particles have not attained a certain degree of hardness; slender selenetic needles, when the salt is deposited by standing water, or in situations where the water is dried up; and stalactites, when the water impregnated with it flows

slowly over hard surfaces, or falls in drops from a certain height.

Gypsum is frequently found under regular shapes. Its primitive form is that of a right quadrangular prism, the bases of which are oblique-angled parallelograms, having their angles at 113° 7′ 46″, and 66° 52′ 12″.

The most usual modification of this primitive form is that of a flattened rhomboidal hexahedral prism terminated by dihedral summits.

The sulphate of lime is found variously coloured. It is sometimes of a dull white, but frequently of a very beautiful pure white, in which case it exhibits a rough-grained fracture, covered with brilliant points; and it is this last kind that is held in the greatest estimation.

Ash-coloured gypsum abounds in numerous quarries; when calcined, it is found an useful material in the construction of buildings; but sculptors and modellers reject it on account of its dark colour.

Very frequently gypsum partakes of all the various shades of colour from a pale to a deep-red; a circumstance that obviously proceeds

from particles of the oxide of iron, and is particularly observable in those strata of gypsum, which, formed in pyritous marl pits, are naturally intermixed with sulphates of iron, which the waters carry along with them, and decompose. This colour remains even after calcination, which does not however prevent the gypsum being used as a cement, though it renders it unfit for the fabrication of those ornamental works in which whiteness is desirable.

I have observed blackish gypsum underneath the fountain of Petroleum, or rock oil, near Gabian. It is in large blocks, several feet thick, and nearly detached from the mountain, displaying a curious assemblage of shining crystals blackened by the petroleum. It is rendered whiter by calcination, but never acquires that degree of pure whiteness, which is observable in some specimens of calcined gypsum.

In quarries of gypsum, large portions of it are frequently found in the form of crystals; those of Montmartre, near Paris, have supplied all the cabinets of natural history in Europe, with specimens of it in this state; they

are indeed so abundant, that a great portion of them is calcined in order to procure a pure and white alabaster for various delicate works of art.

But with whatever readiness this sulphate may crystallize, all the circumstances, which are necessary to produce it in such a form occur so rarely, that for the most part, it is found only in a very imperfect state of crystallization.

With a view to obtain the sulphate in crystals, it is necessary that it be previously dissolved in water, that all agitation be carefully avoided, that the constituent parts of the salt be perfectly pure, and that the evaporation be conducted in a slow and gradual manner. But as all these circumstances seldom concur in its natural formation, it is not often found in numerous and regular crystals; occasionally, however, these are met with in the cavities which exist in the rock, and on the edges of the chinks, or crevices, through which the seleniuic waters fall into the hollows underneath.

Crystals of gypsum are also found in marly

clays, in which pyrites has undergone decomposition, since the small crystals of sulphate of lime, formed in this soft paste, are attracted to each other by the power of affinity, and thus gradually acquire a considerable size. We can almost trace with our eye the process employed by nature in the formation of these crystals in the pyritous marl pits near Montpelier, and especially in those between Foncaude and Lamousson.

The crystals of gypsum are semi-transparent, and of a glossy appearance. Their colour inclines to yellow.

They have such a great resemblance to foliated talc, which is frequently employed as a substitute for glass in lanterns, and windows, as to have been confounded with it by some very eminent naturalists, and they have given them in common the names of *glacies mariæ, lapis specularis*, &c.

The researches of Margraaf have removed every doubt respecting the nature and constituent principles of gypsum, which he succeeded in decomposing, and producing at pleasure; and his experiments proved, that it is composed of lime and sulphuric acid. Ac-

cording to Bergmann, these two principles are in the following proportions:

46 acid,
32 lime,
22 water.

Mr. Kirwan has determined the proportions in three different states of its calcination: at

1st 170° of Wedgwood.	2d, red heat.	3d, white heat.
50,39	55,84	59 acid,
35,23	38,81	41 lime,
14,38	5,35	0 water.

M. Chenevix after having exposed a portion of gypsum, in a crucible of platina, to an intense heat, found 57 acid, and 43 lime. But this substance is rarely found in a pure state, or free from a mixture of other salts.

The younger Rouelle observed an efflorescence of crystals of sulphate of magnesia upon some newly applied plaster of Paris.

This efflorescence is still more abundant in the gypsum used in the south of France; it is indeed

so considerable, as to cover its whole surface, particularly in damp situations, and it is impossible to employ it in the open air, as it would be very soon dissolved by the rain. It has been fully demonstrated, by repeated and accurate analyses, that the gypsum employed in the South of France contains a portion of the sulphates of iron, soda, and magnesia.

Gypsum is very much used in the arts. It is indeed the principal material employed in the making of stucco, and is equally necessary to the modeller, and the fabricator of various ornamental articles of furniture. The same preparation is necessary to render it fit for these various purposes: indeed, in every case wherein it is used, calcination is previously necessary, but the processes, by which this operation is performed, differs in different countries.

1. In several places, they reduce the gypsum to powder, and then throw it into a cauldron, under which a fire is kindled, and kept up until a degree of agitation is produced, similar to the boiling of liquids. The mass is gently stirred during the continuance of this kind of ebullition. At the end of a short time

it ceases, on which the fire is withdrawn, because it is evident, that it was produced by the evaporation of the water, which having now wholly escaped, the calcination is known to be complete.

This process has the advantage of calcining the gypsum in a very equal manner; but it is less economical than many others, on account of the preparatory operation of bruising, and the impossibility of preparing a large quantity of it at one time.

2. In almost the whole of the gypsum quarries, in France, it is broken into small fragments, with which they construct vaults, in a dry situation, under cover of a kind of shade; underneath these vaults a fire is lighted, and kept up till the gypsum has acquired a red heat, when the fire is withdrawn, and the vaults broken down; after this the calcined stones are bruised by means of common hammers. It is in this way that the white and grey powder of gypsum, sold in the shops, is prepared.

Any of the stones which do not readily yield to the hammer, are laid aside in order to be recalcined.

This process, which is equally simple and

economical, is usually employed in order to prepare gypsum in large quantities; but as it is difficult to calcine, in an equal degree, all the fragments, on account of the inequality of their size, and the place which they occupy in the furnace, recourse is had to the following process, when it is required to be of a very pure quality.

3 Having brought to a red heat an oven, similar to that used by bakers, the fire is withdrawn, and a sufficient quantity of gypsum thrown in, after having been previously broken into pieces, about the size of nuts; the oven being then carefully closed and luted, it is suffered to cool before the gypsum is withdrawn.

When it can be obtained in crystals for this purpose, they are preferred on account of their greater purity, and from being more easily calcined.

In order to judge of the alteration produced by calcination on sulphate of lime, it is only necessary to place a small portion of it on charcoal, or on any other heated body whatever, when its semi-transparent hue is soon changed to a dull white, the laminæ separate and exfoliate, and water is disengaged in the

form of vapour. When the evaporation terminates, the specimens found to be friable, and easily reduced to powder between the fingers.

But whatever mode of calcination is employed, the object to be attained by it is always the same, since by this process, the sulphate of lime is deprived of its water of crystallization, and thus rendered whiter, opaque, pulverulent, and capable of re-absorbing water with the greatest avidity.

If the calcination be imperfect, the sulphate partly retains its solidity; it cannot be intimately mixed with water, and the paste thus formed does not readily assume those shapes which the artist may wish to impress on it. Besides, this paste does not acquire a sufficient degree of hardness on exposure, nor take on that beautiful polish, which can be given to that made with perfectly calcined gypsum.

On the other hand, when the calcination is pushed too far, the paste is not sufficiently coherent to answer the purpose of the artist.

When the gypsum has undergone a proper degree of calcination, it absorbs water with great avidity, giving out much sensible heat, and if this fluid be used in a proper quantity,

the paste very soon acquires a great degree of hardness, without however recovering its original brilliancy.

The property which it possesses of imbibing water, and of forming with it a soft paste capable of receiving any impression, and the rapidity with which it hardens, render this sulphate particularly applicable to the formation of statues and all kinds of ornamental figures cast in moulds. It also forms, on the same principle, an elegant covering for walls, as well as an excellent cement for connecting stones, metals, wood, &c.

But the sulphate of lime is not only employed by artists in the formation of our principal ornaments, but they have succeeded in making it assume various colours, and they have attained the secret of imparting to it greater brilliancy, and rendering it more susceptible of a fine polish, when mixed with mucilage or isinglass.

It was this process that gave birth to the art of stucco-making. We find the first rudiments of this art in Hunckel, who mentions several methods which were employed in order to colour gypsum; such as mixing it with

fluids coloured with red saunders, Brazil-wood, saffron, &c. and he suggests the employment of isinglass, in order to give a proper degree of cohesion to the whole, and to render it more brilliant.

Since the time of Hunckel, the art of stucco-making has made the most astonishing progress; they not only execute the most valuable works in stucco, but are now enabled to give to it the fine polish of the most beautiful marble, and that exquisite richness of colouring which appeared to be solely confined to painting in fresco.

The stucco-makers who are anxious to obtain the purest gypsum, usually select it themselves, and, after breaking it into small pieces of an equal size, calcine it in an oven according to the method already described. The fire is withdrawn as soon as they perceive that the largest fragments have lost their brilliancy, and that the whole mass is become opaque, and of the same colour. The calcined powder is then passed through a very fine sieve, and mixed up as it is to be used with a solution of Flanders glue, and it is in this solution that they diffuse the colours with which they intend

to paint the stucco. But when the work is to be of various colours, or to be ornamented with designs, they prepare each colour separately, and afterwards mingle, and combine them nearly in the same manner as a painter mixes on his pallet the primitive colours which are to compose his different shades.

In order to give to his work the glossy lustre so much admired, he rubs it with a pumice stone in one hand, while with the other he cleans it by means of a wet sponge. He next proceeds to polish it with tripoli and charcoal and fine soft linen, and after going over it with a piece of felt dipt in a mixture of oil and tripoli, finishes the operation by the application of pure oil.

All naturalists agree that the sulphate of lime is not of very ancient origin.

It is found in strata superincumbent on calcareous earths and frequently in the immediate vicinity of secondary schistus mountains; and it has never yet been proved to exist underneath granitic or any other primitive rocks.

It appears from the disposition of the strata of gypsum, 1st, that their formation is even posterior to that of the calcareous and second-

ary schistous mountains; 2d, that they are only formed in places where pyrites has undergone decomposition. The first of these positions is fully established from the situation of the strata themselves, since they are never found, but above the mountains of which we have spoken.

The second is demonstrated by an examination of those places where gypsum quarries are usually found, and from the nature of the earths in which crystals of sulphate of lime are formed.

One circumstance which has not escaped the observation of naturalists is, that while the bones of many terrestrial, and fresh-water animals are discovered in quarries of gypsum, no remains of any marine animal were ever found in such situations. From the above fact, it is obviously deducible, that the strata of gypsum, or sulphate of lime have originated from depositions formed in the immense lakes with which the surface of our globe appears to have been covered, before the labours of civilized man, earthquakes, volcanic eruptions, inundations, &c. converted them into rivers. We may observe, by the way, that it is from

those lakes, the great primitive rivers, of which the beds that exist at this day attest their magnitude, derive their origin. An explanation of these facts, and their application to the formation of the gypsum quarries, at Montmartre near Paris, are given by M. Lamanon, in the Journal de Physique, for 1782. It is indeed impossible to account for the formation of such extensive quarries of gypsum, without reverting to the remote period when this earth was covered with masses of pyrites; this primitive state of things appears fully proved by the traces of many volcanoes now extinct, by the existence of beds of ochre, and by the veins of pyrites, and of sulphureous argil, which still remain in their primeval state.

The decomposition of these sulphurets have given rise to the formation of sulphates of iron, lime, alumina, and magnesia, according to the nature of the earthy and metallic matters with which the sulphur enters into combination. We daily witness this phenomenon in the decomposition of argillaceous marls, as we can readily perceive a prodigious quantity of minute crystals of ulphate of lime, which ac-

quire a considerable size, when the argillaceous mass is sufficiently soft to admit of their union with each other.

After what has been said, it is easy to conceive, that if the mass of pyrites be considerable, and if the sulphate be carried off by the waters in proportion as it is formed, and afterwards deposited, beds of gypsum must be formed of an extent proportionable to the greater or less influence of the causes concurring to produce them; and no cause, in our opinion, is adequate fully to explain the effect in question, but the existence of vast lakes, which, receiving the products of the decomposition of pyrites, have deposited them in particular places, in like manner as the waters of the ocean accumulate the remains of marine animals, so as to form calcareous mountains.

The existence of these pyritical masses, whose origin appears to be posterior to the period at which the earth began to be peopled, since no traces of them are discoverable in the primitive mountains, have produced the most astonishing changes on the surface of our globe; without their agency, numerous saline substances would have remained unknown;

neither would those metamorphoses, decompositions, and compositions have taken place, which have renovated the surface of our planet, and shaken it to its very foundations, by the terrible volcanic eruptions to which they have given birth.

Every part of this immense surface of the earth bear more or less recent marks of the decomposition of pyrites; sulphates, ochres, volcanic relics, and warm springs, all concur to evince the activity of this cause, which appears however, to be daily becoming less powerful, though it is unquestionably to the same agency that we must impute those wonderful changes, which at present we frequently witness in mineral substances.*

The transition of gypsum into a state of silex, and to calcedony, has been frequently observed. M. Carozy, director of the mines in Poland, published some observations on this

* We would not be understood as wishing to restrict the production of sulphate of soda to the decomposition of pyrites, though we regard it as the most powerful and common cause of its formation.

subject in 1783. M. Macquart, in a northern tour, afterwards confirmed the facts stated by this mineralogist, which, with his own opinions, are given to the world in a collection of memoirs on mineralogy; and Monnet has described, in the Journal de Physique for 1785, the transition of the gypsum into a state of silex in the quarries of Menil-Montant; from all which facts and observations it has been too hastily concluded, that the conversion of these substances into each other takes place; but chemical science rejects this erroneous doctrine, and beholds in these changes nothing more than the substitution of one body in the place of another, a phenomenon which is neither uncommon in chemistry nor in natural history.

SECTION IV.

On the Combinations of Sulphuric Acid with Magnesia.

The various appellations given, at different times, to the sulphate of magnesia, are derived either from the springs from which this salt

has been procured, from the characters distinguishing it, or from the uses to which it is applied. Hence the various names of *Epsom salt, salt of Sedlitz, bitter salt,* &c.

The sulphate of magnesia is of an intensely bitter taste. Its crystals are tetrahedral prisms with obliquely truncated ends.

That usually sold in the shops is in minute crystals of a snowy appearance, and it is with a view to imitate this form, that the manufacturers of sulphate of soda endeavour, in the way already mentioned, to give this last salt the same appearance, in order that they may dispose of it under the name of Epsom salt. It is, however, easy to distinguish it from the genuine sulphate of magnesia, since it effloresces on exposure to a dry atmosphere, and does not yield magnesia.

There is also frequently substituted in the shops for Epsom salt, a mixture of these two sulphates with several earthy muriates, which is procured from the mother-waters of the salt springs of Lorraine, and Franche-comté, in like manner as from the salt marshes in the South of France.

Epsom salt is soluble in its own weight of water, at 60 degrees of Fahrenheit.

It liquefies by heat, and loses one half of its weight by calcination; the residue requires for its fusion an intense heat; hence, it appears, that this salt, like the sulphate of soda, and others of a similar kind, is subject to two kinds of fusion. Its constituent principles are as follow:

In Crystals.	Desiccated.
29,35	63,32 acid,
17,00	36,68 magnesia,
53,65	0 water.

Few waters contain sulphate of magnesia, but some mineral springs furnish it in such abundance as amply to compensate the trouble and expence of procuring it. It is particularly obtained, in a very pure state, from those of Egra, Epsom, Sedlitz, and Seydchutz: sea-water, and that of salt-pits yield it in a greater or less quantity, but always mixed with sulphate of soda.

As magnesia is one of the most common of

the earthy principles, the decomposition of pyritous schistus gives rise to the formation of sulphate of magnesia. Sometimes even, the magnesia so predominates over the other earthy elements of this pyritous schistus, that the efflorescence is almost entirely composed of the sulphate of magnesia. I have myself witnessed an example of this kind in the schistous mountains of Rouergue, in the department of Aveyron, near the village of St. Michel, about two leagues from St. Sernin.

Similar observations have been made by M. Tingry, on examining some mountains near Geneva; he even taught the peasants the art of extracting the sulphate from the saline efflorescence by lixiviation, in order afterwards to procure the magnesia from it by precipitation.

I have frequently remarked with much astonishment wild pigeons, and birds of passage descend on the mountain of Rouergue already mentioned, and after greedily feasting on the salt, resume their flight.

Sulphate of magnesia is scarcely at all used in the arts, but magnesia is very much employed in medicine; it is procured by preci-

pitation, from a solution of the sulphate by means of the alkaline carbonates.

From an attentive observation of all the phenomena which occur on the decomposition of this salt by the alkaline carbonates, M. Fourcroy deduces the following conclusions :

1. That the sulphate of magnesia is decomposed by the carbonate of potash.

2. That the carbonate of magnesia remains dissolved in the cold fluid, by the aid of an excess of carbonic acid supplied by the carbonate of potash, which contains it in a greater quantity than is necessary to saturate the precipitated magnesia.

3. That the heat capable of extricating the carbonic acid which is dissolved in the water, precipitates by that means the carbonate of magnesia.

4. That to precipitate the magnesia, without the aid of heat, pure potash must be employed.

5. That equal parts of the carbonate of potash are more than sufficient to decompose the sulphate of magnesia ; and that 125 parts of this sulphate, and 100 of carbonate of potash

yield, after ebullition, 45 of pure carbonate of magnesia.

6. That to decompose 125 parts of sulphate of magnesia, 136 of the carbonate of soda are necessary.

7. That a solution of 100 parts of carbonate of soda, added to a solution of 125 parts of the sulphate of magnesia, at the temperature of 12 degrees (Reaumur), precipitates 0,11 of the carbonate of magnesia.

8. That the carbonate of ammonia does not precipitate the magnesia.

9. That if we heat to 30 degrees (Reaumur) a solution of sulphate of magnesia, into which ammonia has been poured, it effervesces, and becomes turbid; but when heated to ebullition, the precipitate is re-dissolved; and that, if we afterwards evaporate the solution to a fourth of its bulk, it yields, on refrigeration, a triple salt composed of magnesia, ammonia, and sulphuric acid.

10. That if we gradually heat to 60 degrees (Reaumur) a mixture of 125 grains of sulphate of magnesia, and 100 grains of carbonate of ammonia, dissolved in the least possible quan-

tity of water, we procure 45 grains of carbonate of magnesia.

11. That if the solution be exposed to the action of the air, without the application of heat, the carbonate of magnesia assumes a very regular form.

The crystals of magnesia are shining, transparent, and nearly destitute of smell and taste.

This carbonate decrepitates slightly, when thrown on burning coals; it falls into powder without dissolving, and loses 0,75 of its weight It effloresces on exposure to the air, and becomes white and opaque.

One ounce of water at the temperature of 10 degrees of Reamur, dissolves 12 grains of this carbonate. It crystallizes in six faced rhomboidal prisms. It loses its acid by calcination, the residue being pure magnesia, sometimes termed calcined magnesia.

SECTION V.

On the Combinations of Sulphuric Acid with Alumine and Potash.

Sulphuric acid dissolves alumine, and it was supposed until very lately, that alum was nothing else but this sulphate.

The sulphate of alumine crystallizes in soft, thin, brilliant laminæ. It is of an astringent taste, and very soluble in water; is deprived by heat of its water of crystallization, and falls to powder; a greater degree of heat decomposes it, by volatilizing the acid; it undergoes no change on exposure to the air. According to Bergmann, it contains equal parts of the acid and alumine. Margraaf had previously observed, 1st. That the simple combinations of alumine, precipitated from alum, by the alkalies, with sulphuric acid, never formed consistent crystals. 2d. That calcined argil, treated in the same manner, produced crystals of a similar nature. 3d. That the addition of an alkali was indispensable, in order to form alum. 4th. That the earth of alum is one *sui generis*, and

not a chalk, as supposed by Stahl, Neumann, and Pott.

Alum, therefore, is not a simple sulphate of alumine, but a triple salt, composed of sulphuric acid, alumine, and potash. It may be termed a *sulphate of alumine and potash.*

Alum is of an astringent taste, is semi-transparent, swells and boils on hot coals, leaving a light, dry, friable, and opaque residuum of a white colour. It uniformly reddens blue vegetable infusions. Its specific weight is to that of water, 17,109, taking the standard at 10,000.

At 60 degrees of Fahrenheit, water dissolves a fifteenth part of its own weight of alum; but it requires only 75 parts of boiling water to dissolve 100.

The most common form of alum is that of octahedral crystals, which are usually so grouped as to represent an indented column.

According to the analysis of M. Vanquelin, 100 parts of alum contains

49 sulphate of alumine,
7 sulphate of potash,
44 water.

Of all the saline compounds, alum is the most generally employed; it not only forms the mordant of most colours, but is used in a variety of other operations, and is therefore, under all its relations, deserving of the greatest attention.

In order to convey to our reader a clear and distinct idea of this substance, it is proper to consider it under two separate divisions. In the first we shall treat of *native alum*, and in the second of *artificial alum*.

ARTICLE I.

Of Native Alum.

We give the name of *native alum* to that which is procured directly from the mines, not that it is of a different nature, but because the mode of treating the mineral, and extracting the salt, forms a series of interesting operations, and because the alum of commerce is mostly obtained from this source.

Bergmann has divided alum mines into two different kinds: 1st. Those in which it is ready

formed; 2d. those in which are contained only its principles, or elements.

The mine of Tolfa, near Civita Vecchia, is of the first kind; Bergmann informs us, that there the alum exists ready formed.

At Solfatara, near Puzzoli, the lava daily effloresces, and forms alum. Bergmann procured from it 8,00 alum, and 4,00 of pure argil; the remainder was silex. It would appear, that the alum mines of Piombina are nearly of a similar nature.

At Saint Aubin, near Cransac, in the department of Aveyron, there is a very abundant alum mine, in which the salt is also found ready formed.

Aluminous efflorescences are frequently found on secondary schistus, in a state of decomposition.

It is evident, that this native alum, and that procured by art from schistous minerals, have the same origin. In the first case, the decomposition, by which the alum is formed, is, so to speak, spontaneous; whereas, in the second, it is produced by subjecting the rough mineral to a particular process.

The two species of mines, therefore, distin-

guished by Bergmann, might, we think, be with greater propriety considered as one and the same. Wherever there is found a mixture of alumine, iron, and sulphur, there exist the primary elements of the two sulphates, which are almost inseparable; and we may regard, as alum mines, those enormous masses of secondary schistus, which constitute such a large portion of our globe.

This schistus is sometimes impregnated with bitumen, or a kind of pit-coal, and we may rank amongst alum mines almost every schistus of this nature.

The constituent principles of aluminous schistus are nearly the same every where; bitumen, alumine, silica, lime, magnesia, iron, and sulphur. They differ merely in the proportions. The iron is uniformly found united with the sulphur, and it is the decomposition of this sulphuret which occasions the formation of the sulphuric acid, and consequently of the sulphates of alumine, and iron; frequently, even this last sulphate is not intermixed with the other materials, but is found in small crystals dispersed throughout the mass.

According to the predominance of one or

other of these principles, the product of the decomposition will be different, as well as the object with which such mines are wrought. Thus, for example, when the bitumen is very abundant, with only a small proportion of the earthy, and metallic principles, the mineral is termed pit-coal, and is dug up for the purpose of burning. When the iron predominates, the mine is wrought for the sake of the copperas; and when the alumine forms the chief part of the mass, the object in view is to procure the alum. Sometimes the iron and alumine are present in nearly an equal proportion, constituting a species of *mixt mine*, from which the two sulphates may be extracted.

But in whatever proportions the different principles are found, or whatever may be our object in working these mines, the operations by which this is performed, are conducted on general principles, applicable to all cases.

1. As alum does not exist in the mineral ready formed, the operation, by which its formation is accomplished, we term *aluminization*.

2. After the formation of the alum, it is necessary to extract it, and this is performed by the process denominated *lixiviation*.

3. When the lixiviation is completed, the next step is to crystallize the alum, and this third operation is termed *crystallization.*

SECTION I.

On Aluminization.

The mineral from which alum is procured, contains sulphur and alumine, but not the sulphuric acid ready formed. Its formation therefore requires to be effected by artificial means, in order that it may enter into a state of combination with the alumine. As sulphur is the radical of the sulphuric acid, it only requires to be combined with oxygen in order to produce this acid.

This combination is accomplished by exposing the mineral to the action of air and water, and favouring their decomposition, and the union of the oxygen thus disengaged, with the sulphur it contains, by the different methods about to be described.

The action of air and water, however, is extremely slow in its operation, unless other means be employed to hasten the combination.

With this view, therefore, the mineral is first powdered, in order to increase its surface, and then slightly moistened with water, so that a greater quantity of oxygen may be brought into contact with it, and in a more condensed form, and gentle heat is afterwards employed to promote the combination.

It is in the proper regulation of these different agents, *air*, *water*, and *heat*, that the art of *aluminization* consists.

It must not, however, be understood, that these means are to be uniformly and constantly employed, since the nature of the mineral, and other circumstances requires that they should be variously modified.

When the mineral, for instance is soft, porous, lamellated, and friable ; when it is in the form of a loose, dark, or very black earth, no preparation is requisite, except forming it into a heap upon a hard clayey soil, with the sides gently inclining, so that the waters which flow over their surfaces, may fall intoa ditch du gat each side of the heap, in order to receive them.

These waters are allowed to deposit the various undissolved matters they have carried along with them, after which, they are poured

into basins, in which they are suffered to remain until they become sufficiently clear, and afterwards turned over into proper evaporating pans.

The mine of Schwemsal, in Saxony, is of this kind; this mineral is generally formed into heaps of 100 feet in length, by 20 or 25 in breadth, and from 12 to 15 in height.

They remain exposed to the air during a period of two years previous to lixiviation, when they are found to be almost wholly in a state of efflorescence, or if some fragments still preserve their primitive form, they fall to powder on the touch, and display the alum ready formed between their strata.

This mineral furnishes only two pounds of alum per quintal.* The heat generated in the progress of aluminization is frequently so considerable, as to inflame the mass, in which case, in order to arrest the progress of the combustion, the heat is opened at the point whence it appears to proceed, by which means the heat becomes diminished.

At Helsingburg, in Scania, there is a species of turf formed by the decomposition of ve-

* The French quintal is 1 cwt. English. T.

getable matters, and their mixture with aluminous pyrites, from which a great quantity of alum can be extracted by lixiviation.

We cannot, however, rank under this class, the *fat coal*, as it is termed, which is in fact, nothing more than a species of turf of a very sulphureous nature, and which exhales on burning an extremely disagreeable odour. Strata of this coal, which is of a very indifferent quality, are frequently found in marley soils, and may be wrought with great advantage for the sake of the alum. It is readily decomposed by the air, leaving a residuum of red ashes; in order to promote the efflorescence, it is disposed in beds above each other, and carefully watered, in proportion as they are formed.

When the heap is raised to the height of from eight to ten feet, it is suffered to remain until the surface be wholly covered with an aluminous efflorescence, which usually happens at the expiration of eight or ten days, after which the surface is again occasionally watered during another week. If, at this period, the heat be so powerful as to threaten inflammation, a new heap is formed, by turning over the beds one by one, taking care to water each

with the same caution as at first. But whether the beds become heated or not, they are turned over at least once a month. Several establishments have been founded in Picardy, in France, in which the operations are conducted in this manner.

When the mineral is hard, and consequently of slow decomposition, heat must necessarily be employed in order to promote its efflorescence.

This circumstance furnishes us with a very natural division of these mines; the one contains the bitumen requisite to produce their calcination, the other is wholly destitute of this principle.

The famous mine of Garphytan, in Sweden, belongs to the first class; this mineral is formed into beds composed of a stratum of bituminous schistus, which is kindled, and over which are placed others that become inflamed in their turn; when the fire slackens or goes out, it is re-kindled by means of lighted faggots; and the calcination is usually completed in the course of one month.

There is a mine of this kind near Milhaud,

in Aveyron, from which alum is obtained by a similar process.

The mines of aluminous coal, of which we have already spoken, can be wrought with great advantage in the same manner, since by this means the efflorescence is greatly facilitated. When the coaly heap is inflamed, the aluminous ashes, which are formed on its surface, are thrown down from time to time, by which means the stratum immediately below becomes inflamed in its turn, and so on with the rest, until the whole mass is gradually reduced to a state of ashes. This mode possesses even some advantages over that of spontaneous efflorescence, since the alum thus obtained does not contain an excess of acid, and is otherwise of a much superior quality.

But when the mineral either does not contain the bituminous principle, or when it is present in too small a quantity, to produce its decomposition, recourse must be had to some extraneous combustible, and with this intention faggots of wood are usually employed.

At Whitby, in the county of York, a rock of twelve miles in extent has been discovered,

which affords a most abundant vein of alum. They first tear open this rock, after which the different fragments are loosened in form of plates or leaves, in the same manner as schistus; it is of a dark grey slate colour, and between its laminæ are discovered small grains of pyrites, belemnites, and a great portion of cornua ammonis, or serpent-stone. With a view to aluminise this mineral, a bed of faggots is formed, of from 10 to 12 feet in thickness, by the side of which a scaffold is erected, which enables the workmen to form a pile of mineral of about fifty feet in length, and forty in height. They do not wait until it is finished before lighting the fire, because as it penetrates the mass only slowly, it is necessary frequently to renew it.

The mines of Sweden, Norway, Hesse, and the duchy of Liege, are wrought nearly in a similar manner, but in several of them the combustible and the mineral are stratified; that is, a bed of faggots and mineral are placed alternately over each. By this method, the calcination is performed more equally, but it is attended with considerably greater expence.

Elsewhere, the director of the mines has not the power to employ either of these modes indiscriminately, but the choice is determined by the nature of the mineral itself. When, for instance, after being once heated, the decomposition continues to go on without any additional heat, a single stratum of combustible matter is all that is requisite, in order if we may be allowed the expression, to impart to it the first movement, after which the efflorescence is propagated, and carried on spontaneously. But on the contrary, when the mine cannot be wrought without the aid of extraneous heat, it is then necessary to stratify it with some combustible body, in the manner already mentioned. Most of the mines in which pyrites is found, in the form of cubes or octahedrons, belong to this last class. But when the pyrites is diffused throughout the paste, and more particularly when it is in a state of combination with it; then it is sufficient to communicate to it the first impulse, in order to produce the vitriolization of the whole mass.

We shall have occasion to observe in the next chapter, that when the sulphur is too

abundant in the pyrites, no efflorescence takes place, and on applying this principle to alum mines, it will be evident that the calcination of the mineral has for its object not only to disengage the superabundant portion of sulphur, but to facilitate its combination with the oxygen.

In several establishments of this kind, as at Dilta, in Nericia, the pyrites is first distilled in order to free it from the sulphur, after which the residuum is left to effloresce in the open air, and when this process is completed, they extract from it, by lixiviation, the sulphates of iron and of alumine.

All mines containing native alum derive their origin, either from volcanic fires, or from the spontaneous decomposition of pyritic matter. In this case calcination is useless, unless when the mineral is so hard, as not to yield to lixiviation, and it is then necessary to soften it by the application of fire.

The alum mine of Tolfa is so extremely hard, that it can only be wrought by means of gun-powder, or by picks.

According to Fougeroux, the greyish-yellow stone, which forms part of this mine, is the

most valuable, but the preference is given to that which is white by the abbe Guenée.

The rock alum on being detached from the mine is immediately thrown into a furnace, for the purpose of calcination, which very much resembles a lime kiln, heated by coals, where it is allowed to remain during the space of three hours. Bergmann remarks, that the fire is extinguished, whenever the flame becomes white, and the odour of sulphuric acid begins to be perceived. The calcined mineral is then piled up in a large heap, until the whole can be reduced into a paste by the hand.

From the analysis made by Monnet of some specimens brought from the mine of Tolfa by Guettard, it appears to consist of a combination of argil, sulphur, and potash, but Bergmann, who analyzed it with still greater accuracy, found that it contained native alum enveloped in much argil.

Guy Lassac, who had himself occasion to witness the phenomena produced by the calcination of the rock alum of Tolfa, observed that there were disengaged from it sulphureous acid and oxygen, from which it is evident that a decomposition of a portion of the sul-

phuric acid had taken place, and a necessary augmentation in the quantity of alumine. Hence Guy Lassac concludes, that in this stone, previous to calcination, the sulphuric acid is combined with a greater portion of alumine that it can saturate, so that an insoluble salt is formed; whereas, after calcination, the alum recovers its true principles, and in the most just proportions, so as to render it susceptible of lixiviation.

The ore of Salfatara is porous, friable, and spongy. Alum is there produced spontaneously, and the mineral requires merely to be lixiviated in order to furnish the salt which it contains.

A natural efflorescence is observable in most alum mines, which is sufficiently indicative of their character, and by which we may form a certain judgment respecting the abundance and purity of their products; and this efflorescence chiefly appears in those places abandoned by the workmen, and in dark, damp cavities, where there is a perpetual stagnation of air. When the efflorescence is external, it is rendered very evanescent by the action of light, and rain water.

From what has been said, it must appear evident, that the propriety of adopting any particular method of working a mine must wholly depend on having previously ascertained the true nature of the mineral it contains.

Calcination properly conducted, a long exposure of the mineral to the action of the air, watering, and stirring it occasionally, favour the efflorescence, produce an intimate combination between the acid and alumine, and oxydize the iron, so as to render it insoluble, &c. from which it is evident, that the quality of the alum must be greatly influenced by these preliminary operations.

SECTION II.

Of Lixiviation.

We have already observed, that native alum is not found in mines, but that the combination of oxygen with sulphur forms sulphuric acid, which, uniting with the earthy and metallic principles, produces the sulphates of alumine, lime, magnesia, and iron, intermixed with each

ether, in various proportions, according to the nature of the mine.

All these sulphates may be extracted by lixiviation, but as the object in working alum mines is to obtain the sulphate of alumine separately; the means employed for this purpose must be variously modified according to circumstances, since in one case the sulphate of iron predominates, in another that of magnesia, &c. and the nature of each salt requires particular operations.

In all extensive manufactures, the mineral after being calcined, and allowed to effloresce, is subjected to lixiviation in large shallow vessels strongly constructed, and sunk in the ground, in order to preserve as much as possible an uniformity of temperature. These vessels are disposed in parallel ranges, so that the waters may be poured from one into the other; in some situations the declivity of the ground at the base of the aluminous strata, admits of their erection in this manner. In the superior range is placed the mineral, which has already been lixiviated, and nearly exhausted; in the second, that which has undergone one lixiviation at least; and in the

third, the pure mineral after calcination; so that the water may gradually take up the different salts, and acquire a degree of concentration amounting to from 15 to 25 degrees, according to Baume's areometer, preparatory to the subsequent process.

In some manufactures of this kind, only a single range of vessels is employed for the lixiviation of the mineral. At Whitby, in Yorkshire, the mineral is twice lixiviated, and the water left to act on it twenty-four hours; the precaution, however, is employed of pouring the water of the second lixiviation on the pure mineral. A similar method is pursued at Schwemsal in Saxony.

In order to lixiviate the mineral very accurately, it is requisite, 1. That it be suitably divided, so that the water may penetrate it more effectually, without however being pulverized, as in this case, it is apt to become amassed in a heap, which renders it necessary to mix it with straw, or fragments of the mineral itself, to bring all its parts into contact with the water.

2. That the water should cover the mineral by several inches.

3. That the mass of mineral be of a certain thickness, for the water becomes impregnated with saline matter, in proportion to the height of the stratum through which it percolates.

4. That the water be suffered to remain, until it ceases to act.

It is of importance to make the vessels, in which the lixiviation is performed, of suitable dimensions; with this view, their size ought not only to be adapted to the quantity of mineral intended to be lixiviated, but to the subsequent operations in which they are to be employed. Thus, though strait deep vessels are very proper for the purpose of lixiviation, they are not equally convenient for the extraction of the exhausted mineral.

The water of lixiviation is next put into large reservoirs constructed of solid stone, in which it is suffered to remain for some time, in order to become clear by the deposition of any extraneous matters, with which it may happen to be mingled, as ochre, suspended alumine, and sulphate of lime, after which it is poured into the evaporating pans.

The lixiviated mineral not being fully deprived of the whole of its alum, is in many

manufactories formed into heaps as at first, and suffered to remain until it again assumes a state of efflorescence. This practice is followed at Schwemsal, in Saxony; but in other works of this kind, the lixiviated mineral is re-calcined, in order to draw from it a new store of alum; that of Christineoff in Sweden, undergoes twelve calcinations, before being finally thrown aside as useless. Where fuel can be procured at a cheap rate, it might prove advantageous to perform lixiviation by means of hot water; for, as alum is from fifteen to twenty times more soluble in boiling water, than in that at the ordinary temperature of the asmosphere, the lixiviation would thus be accomplished more speedily, and the evaporation carried on with greater rapidity: in this respect, however, as in all the other operations, a great variety of local circumstances must be taken into account, which can only be properly done by an intelligent director stationed on the spot.

We cannot be persuaded, that wood is the only material proper for the construction of lixiviating vessels; they might unquestionably be equally well formed of various stoney or earthy materials. For example, the sides and

bottoms might be constructed, in the most solid manner, of grey quartz, granite, or schistus. Pouzzolana, the earth deposited by hard waters, pounded bricks, quartzy sand well washed, and mixed with good lime, would form excellent mortars for this purpose. Particular attention ought to be paid to render the bottoms extremely solid, since they have not only to support the whole weight of the water, but because any deficiency in this part does not become evident, until it be too late to remedy it, without much difficulty.

These basins may be brought to the greatest degree of perfection, by covering their internal surface with a varnish composed of equal parts of yellow wax and resin melted together, and afterwards mixed with Spanish brown, or Pouzzolana well sifted, until it becomes of a proper consistence to be laid on with a brush. It is of importance to employ this varnish as warm as possible, and not till the basin is perfectly dry, in order that it may more effectually penetrate into the mortar.

Over this coating should be applied a second, composed of the same materials, but containing a much less proportion of Spanish

brown, and having a third of oil of turpentine added to the melted oil and wax, which renders it more pliant, and prevents those cracks and fissures that occur in the first coating by the dessiccation, or the contact of the salts.

SECTION III.

Of Crystallization.

The evaporation of aluminous lixivia is performed in Britain, Sweden, and Norway, in large leaden caldrons, from 10 to 12 feet in length, 7 to 8 in breadth, and from 2 to 3 in depth.

These enormous caldrons are fixed on bars of cast iron, from 6 to 7 inches in diameter, over which a bed is formed with flat plates of iron, in order to support the bottom of the caldron. The sides of the furnace are constructed of brick.

The caldrons employed in the manufactures at Hesse and Liege, are much smaller, being only from 7 to 8 feet in length, by 20 to 22 inches in depth.

In some establishments, in order to augment

the heat, two fire-places are constructed, under each of these enormous caldrons, and the flame from these two fires is united in one common chimney.

At Solfatara, the natural heat of the soil is sufficient for the evaporation of the lixivium. The caldrons are therefore sunk in the ground, by which means they are constantly exposed to a heat of 45 degrees of Reaumur; and the evaporation, though slow, is uniform, and carried on without the aid of artificial heat. In works of this kind, conducted on a judicious plan, the evaporating vessels, or caldrons, are so disposed, that the water of lixiviation can readily flow into them, by a natural declivity. With this view, their superior edge is placed a little below the level of the bottom of the reservoir, which contains the lixivium. The vessels are first filled with the lixivium, and afterwards occasionally supplied with an additional quantity, in order to make up for the loss of that expended by evaporation. This evaporation is kept up during several days, and when the liquor is judged to be of a sufficient strength, the *mother waters* of former operations are added, in order to bring it more

speedily to the requisite degree of concentration.

In many such establishments, the *mother water* is put into the caldrons, previous to the introduction of the lixivium, while in others, on the contrary, it is added towards the conclusion of the boiling. Of these two methods, the last appears to me to be the most advantageous, because the mixture of the *mother water* retards the evaporation, and consequently renders the boiling more tedious, by condensing the liquor at the commencement of the process.

During the process of boiling, it is of use to agitate the liquor, not only as it favours the evaporation, but operates to prevent the deposition of the sulphate of lime, and other substances dissolved, or suspended in it, as they might injure the caldrons by forming a crust, which, interposing between the fluid and the metal, would expose this last to the direct action of the heat.

One of the most difficult parts of this process is, to determine the proper time for terminating the evaporation, and draining off the liquor. In some alum works, the liquor is

concentrated to 60 degrees of Baumé's areometer, while in others, it is not carried beyond 35 degrees. As great differences are, however, produced in this respect, not only by the nature of the salts mingled with the alum, but also by the proportions they bear to each other, experience alone can determine the proper point to which the evaporation should be carried; hence, in different establishments, various tests are employed to ascertain the proper degree of concentration; in some the boiling is supposed to be carried to a sufficient length, when a fresh egg remains buoyant on the surface of the lixivium, while in others they weigh the liquor in a bottle to compare its weight with that of pure water. Another method is, to fill a cup with the liquor, in order to ascertain whether it crystallizes on cooling. With the same view a given quantity of the lixivium is evaporated by pushing the concentration to a determined height in the caldron. These tests, though not extremely accurate, are yet sufficiently so to enable them to conduct such operations with the requisite precision.

If the lixivium, properly concentrated, were

poured in this state into the crystallizing vessels, we should obtain, in most instances, nothing but a *magma*, without consistence, and having neither the chemical properties, nor the forms of the alum of commerce. To that liquor it is necessary to add a certain portion of alkali, in order to obtain what is properly called alum.

It is strictly true, that there is no alum which does not contain a portion of alkali; but, in order to obtain alum, it is not necessary to add alkali to the produce of all the mines. M. Jars affirms, that at Christineoff in Sweden, no alkali is employed. It is a fact, that no use of it is made either at the mines of Tolfa, or at Cransac, in the department of Aveyron. The reason is, that these mines naturally contain a portion of potash. Monnet has long ago shewn its existence in the mine of Tolfa.

The mode of employing the alkali differs much in the various places where alum is manufactured. In Saxony, it is not till after the lixivium has been left to boil in a large reservoir for some hours, that they make it pass off into a vat, where it remains eight days, when they add the lixivium of soapboilers, and a lit-

tle putrescent urine. In England, M. Jars informs us, that after the lixivium is properly concentrated, they mix with it the ashes of marine plants, called *kelp*. In Picardy, the lixivium is concentrated to 50 degrees, when the fire is withdrawn. They then pour in from 10 to 20 pounds of potash dissolved in water, to the quintal of alum; the liquor is briskly agitated during the process of mixture, and then drawn off into the crystallizing vessels.

In most alum works they add the potash to the lixivium, because it then occasions a less abundant precipitation.

When the solution contains a portion of copperas, which is not uncommon, the liquor properly concentrated is poured into the crystallizing vessels, and then the copperas is precipitated and crystallized.

It is not till after this separation of the copperas, that the potash is mixed with the solution. A granulated salt is then precipitated, which consists of alum, and the crystallization of which separates the small portion of the sulphate of iron which it contained.

If the mine be very rich in copperas, the *mother waters* are concentrated and set apart

to crystallize a second time, in order to separate a new quantity of crystals of the sulphate of iron; after which potash is added, in order again to obtain alum.

When the liquor is united with the potash, before the separation of the copperas, the alum crystallizes first. On the other hand, it crystallizes second, or not at all, when the potash has not been added, because there is wanting to it a principle, without which it has no consistence.

Instead of employing potash to saturate the liquor, all those salts which contain it, may be used; even soda, and urine in a putrescent state, as furnishing ammonia, will answer this purpose.

The alum obtained from a lixivium to which soda has been added, assumes, on exposure to the air, a dull whitish colour, similar to that of sulphate of soda on beginning to effloresce.

It is curious to observe the instantaneous effect produced by the sulphate of potash on that of alumine. When to the lixivium of the last mentioned sulphate, concentrated to 20 degrees of Baumé's areometer, is poured a saturated solution of sulphate of potash, the

most beautiful crystals of alum are obtained in less than an hour.

All those chemists who have speculated on the action of alkalies in the formation of alum, have only viewed this process as a means of saturating an acid in the state of excess, or of precipitating the oxyde of iron.

Bergmann himself has proposed to saturate the superabundant acid, by pure alumine; but I have proved, that there is then formed a combination very different from the alum of commerce, since the alumine which is added, is precipitated by evaporation in the form of a white earth, insoluble in water, and which assumes no regular form.

If the alkali only served to saturate the superabundant acid, wherefore should not lime, metals, and magnesia, produce the same effect? Why should not the neutral salts, with a base of potash, supply the place of the alkali?

In all these cases the potash combines, not with the acid alone, but with the sulphate of alumine; and hence results the triple salt, denominated *alum*.

It has been observed, that instead of using potash, putrescent urine is sometimes em-

ployed; and even in some manufactories, both are used. Hence it is, that the analysis of different kinds of alum presents sometimes potash, sometimes ammonia, and sometimes both potash and ammonia.

Alum is not brought to its proper degree of purity by a single crystallization. It generally contains too great a proportion of acid, very often a portion of the sulphate of iron, and of that of magnesia, from which it is disengaged by solution in boiling water, and crystallization; for the excess of the acid, and the two sulphates remain in the *mother waters*, after the alum has crystallized. At Whitby, in England, the solution is drawn off into casks, when the alum concretes into a mass; the hoops are then taken off, when it is broken and left to dry, before being put into casks, to facilitate its conveyance.

In other manufactures, such as those of Sweden, Picardy, Norway, &c. the alum is washed with cold water before being dissolved in boiling water. This washing dissolves and carries off the copperas, and the sulphate of magnesia. It is performed in different ways; 1st. upon tables gently inclined, and furnished with

ledges on the sides, and over which an uninterrupted stream of water is made to flow; 2. by means of baskets into which the alum is put, and which is in this state repeatedly plunged into water.

Bergmann justly observes, that alum made without the addition of the *mother water*, is always the most pure; for it is only at the mine of Tolfa, that a mother water is obtained, which contains almost nothing but alum. But the addition of mother waters is useful, not only in respect of economy, since it furnishes a great deal of alum, but also in regard to the time, which would otherwise be employed in evaporation.

ARTICLE II.

Of artificial Alum.

The rapid progress which chemistry has made in the present age, has produced a very useful revolution in the arts: not only has it thrown light on the various processes, but it has even taught the artist how to manufacture the various articles he employs.

It has done still more; for by it we have been enabled artificially to form many of those compound substances which were formerly extracted with much labour from the bowels of the earth; such as alum, copperas, &c. and from the progressive improvement of the different operations employed for this purpose, we may confidently hope, that our manufactures will shortly furnish a sufficient supply for all the purposes of commerce.

The first alum produced in this way in France, was at my laboratory at Montpelier, and at the manufactory of Javelle, in Paris. The processes, however, employed in their formation were very different in these two establishments.

At Javelle, the argil of Gentilly is first calcined, then pulverized, in a mill adapted for the purpose, and afterwards mixed with a sufficient quantity of sulphuric acid. After remaining a few days in this state it is removed to an oven, and exposed during twenty-four hours, to the action of a heat from 50 to 60 degrees of Reaumur. It is then subjected to the process of lixiviation, evaporated, and the urine or potash added in a proper quantity.

At Montpelier the argil, previously pounded, is kneaded up with half its weight of the product from the combustion of the saltpetre and sulphur employed in the formation of sulphuric acid; it is well known that this residuum consists almost entirely of sulphate of potash. Balls from four to six inches in diameter are formed of this substance and carried to a potter's oven to be calcined. They are then disposed on floors and on boards placed for the purpose in the apartment appropriated to the manufacture of sulphuric acid.

By the action of the sulphuric vapour these balls quickly swell, crack, and open, so that at the end of three weeks or a month, they are sufficiently penetrated by the acid, on which they are exposed to the air under sheds, in order that the saturation may be more complete. They are next lixiviated, and the lixivium evaporated in the usual manner.

Since that time this process has been greatly improved by M. Berard, my pupil, and at present the proprietor of that establishment. He carefully mixes the sulphate of potash with the argil; this he forms into balls, which are then calcined, and afterwards sprinkled over

with a quantity of sulphuric acid, of the strength of 40 degrees, equal in weight to the argil employed. This proportion must, however, be varied according to the nature of the argil.

The solution of the earth thus calcined and *potashed,* is accomplished with great rapidity. The acid does not become more quickly saturated with potash, than it does with this earthy and alkaline combination.

M. Curaudeau has also published a process for making alum, which is certain and of easy execution. He dilutes 100 parts of argil in a solution of 5 parts of sea-salt, and forms a paste, to which he gives the shape of loaves, in order to calcine them in a reverberatory furnace. He then reduces the calcined residuum to a powder, and pours upon it a fourth of its weight of concentrated sulphuric acid, carefully agitating the mixture. When the fumes of the muriatic acid are dissipated, he adds a quantity of water equal to that of the acid, still continuing to stir the mixture. A strong heat is thereby produced, the composition swells, he continues to pour in water, and terminates the process by adding a solution of

potash, in which the alkali equals a fourth of the weight employed. On cooling the liquor crystals of alum are formed three times the weight of the acid.

There is another method, which I have for some time pursued in my manufacture at Thernes near Paris, and which M. Bouvier follows at present, with as much success as intelligence. It consists in mixing together 100 parts of argil, 50 of nitrate of potash, and 50 of sulphuric acid, at 40 degrees of concentration. This mixture is put into a still, to which is fitted a receiver, when the distillation commences. The nitric acid is expelled by the sulphuric acid, and when the distillation is finished, the residuum requires only to be lixiviated in order to furnish alum of the best quality.

This process is so much the more interesting, that it furnishes the means of carrying on at the same time two important operations, the fabrication of alum and the distillation of aqua fortis. It is scarcely necessary to observe that the proportions ought to vary according to the nature of the earth that is employed; and that here, it is of the greatest importance to employ

a very aluminous argil, in order to diminish the weight, and to obtain a greater product from the same distillation, augmenting at the same time the proportions of the saltpetre and the acid.

In commerce there is a considerable difference made between the different kinds of alum. On this subject the influence of opinion is such, that every kind of alum bears a fixed price, and the Roman alum is constantly sold at least one-third above that of others.

Some years ago, M. Vauquelin and myself published the result of our analyses, from which it was evident, that the real or supposed superiority of the Roman alum did not arise from an imaginary excess in its base. In a short time, some manufacturers availed themselves of this circumstance, and sold, under the name of Roman alum, a kind that was purified and whitened externally, by a little pure alumine, slightly ochreous, and of a reddish tinge.

The consumer did not at first perceive any difference; but when aware of the imposition that had been practised on him, he rejected every kind of alum bearing the name of Ro-

man, and at present pays the same price for the alum of Messrs. Bouvier, Curaudeau, and others, as for the refined alum of the mines.

Messrs. Roard and Thenard subjected the different alums of commerce to a comparative trial on a great scale, in the celebrated manufacture of the Gobelins at Paris, by which they ascertained: 1st. That all kinds of alum may be used indiscriminately, in the dyeing of wool; even those in which a greater portion of iron than usual is held in solution. 2. That the different qualities of alum were very perceptible in their application to silk or cotton. 3. That all the alums of commerce when redissolved and crystallized, constantly produced the same effect. This interesting series of experiments has decided that important question; and an additional benefit has been thus rendered by chemistry to commerce and the arts.

SECTION VI.

Of the Combinations of Sulphuric Acid with Iron.

The sulphate of iron produced by the union of the sulphuric acid with iron is known even at present under the various appellations of *copperas, sal martis, green vitriol, salt of steel,* vitriol of iron, &c. The first naturalists who noticed this salt have only given us vague ideas respecting its nature; the names bestowed on it, therefore, are all deduced: 1. From the different states through which the pyrites passes; such as those of *chalcitis, sory, misy.*" *Sory transit in chalcitim et chalcitis in misy.*" Pliny. 2. From the different states under which it presents itself; as *trichitis,* which expresses the small loose crystals that are found in the mines; *stalactites,* or that which is found in stalactites; *cupri-rosa,* or that which assumes the form of flowers or dendrites. 3. From the uses to which it has been applied; *atramentum metallicum, scriptorium, sutorium,* &c. The following are the characters of this salt.

1. The colour varies from a whitish green, an emerald green, to a deep bottle green. This variety of colour arises in an especial manner, from the degrees of oxydation of the metal and the proportion of the acid.

2. It is of an astringent, or somewhat metallic taste.

3. It effloresces on exposure to the air, and falls down in a white or yellow colour, according to circumstances which will be afterwards explained.

4. It melts upon the fire, boils, and forms a whitish powder, which by continuing the heat becomes red; and on the application of a more intense heat yields afterwards sulphuric acid.

5. It is soluble in six times its weight of water, at the temperature of 60 degrees of Fahrenheit. Boiling water dissolves one fourth part more than its own weight.

6. It is insoluble in alcohol.

7. The alkalies added to its solutions, precipitate it in white flakes, which suddenly become green With tannin it forms a black precipitate, with prussiate of lime a blue precipitate, and a yellow precipitate with oxalic acid.

8. It crystallizes in rhomboidal prisms, of which it assumes all the modifications.

9. The proportions between its constituent principles are,

According to Bergmann,	Kirwan,
39 acid	26 acid
23 oxyde	28 oxyde
38 water	8 water of composition
	38 water of crystallization.

10. The specific weight, when compared with that of water, is in the ratio of 18 to 10.

Before describing the processes by which the copperas of commerce is formed, I think it necessary to point out the different states of oxydation of which iron is susceptible in its combinations with the sulphuric acid.

Mr. T. Thomson thinks that the black oxyde may unite itself with water, and form a hydrate of a green colour. By this he explains the reason why the precipitates by alkalis are green; he considers the oxide in the sulphate of iron, as being in the state of hydrate, and refers to the disengagement of the water by heat, or to

its solution in alcohol, when the sulphate in powder is presented to it, the white colour which the salt assumes under these circumstances.

This idea of Mr. Thomson's, with regard to the cause of the green colour, is corroborated by a well known experiment. When the evaporation of the solution of sulphate approaches 40 degrees, a white precipitate takes place, which is nothing but a sulphate deprived of its water of crystallization; it is sufficient to dissolve it in water to communicate a green colour, which proves that it is to this water that the green colour is owing.

M. Proust conceives, that the sulphate of iron is only susceptible of two states of oxydation; namely, 27 and 48 of oxygen, to 100 of iron: he does not admit any intermediate degrees.

The first state forms, according to him, the green crystallized sulphate, in which Lavoisier has demonstrated, that the iron contained $\frac{27}{100}$ of oxygen. This salt, when it is pure, says M. Proust, forms a green solution, which is unalterable by the gallic acid, and is not rendered blue by the alkaline prussiates.

The second species of sulphate, according to the same chemist, forms that combination, which is, red, deliquescent, uncrystallizable, soluble in alcohol, unchangeable bythe oxy-muriatic-acid, and which is obtained by treating that acid with the nitric acid, until the solution yields no longer any nitrous gas by the action of the nitric acid. This sulphate forms exclusively a black precipitate with the gallic acid, and a blue one by the alkaline prussiates. In this case the oxydation is carried to 48 in the 100.

M. Proust adds, that if the green sulphates when in contact with the air assume a colour which appears to belong to neither of the two species, it is a proof that it is a mixture. The alcohol will separate the red sulphate from it; and the green sulphate will produce a green precipitate, with the pure or caustic alkalies, acquiring a black colour under water, while the red sulphate will yield a reddish yellow precipitate, unalterable in the air, and by the oxy-muriatic acid.

The pure green sulphate added to a saturated solution of prussiate of potash forms a white prussiate. An extremely pure green sulphate is obtained by adding water saturated with sulphurated hydrogen gas to the red sulphate, be-

cause thus the iron in the state of the red oxyd is deoxygenized.

With a view to preserve the colour of the precipitate, formed by the affusion of the solution of the prussiate upon the green sulphate of iron, the mouth of the flask must be immediately closed. The white deposition quickly acquires a green tint which does not become deeper if the flask be kept shut.

The white is converted into a blue prussiate by the contact of air. In this case, the oxyd of iron acquires the maximum of oxydation, by seizing the oxygen of the air. The acids which can supply the oxygen, such as the oxy-muriatic and the nitric, convert the white into the blue prussiate, more or less quickly according to the facility with which they part with their oxygen.

The solution of sulphurated hydrogen restores to the state of a white prussiate that which had been changed into a blue prussiate by re-absorbing its oxygen. The transition from the white to the blue prussiate is marked by a green tint, which appears to be owing to the existence of a mixture of prussiate and sulphate of potash of a yellow colour.

In every case wherein the prussiate of potash is employed to decompose a martial salt, in which the oxyd is at its maximum, we obtain a blue prussiate upon which the acids cannot act, without decomposing the prussic acid.

Not only does sulphurated hydrogen restore the blue to the state of white prussiate, but plates of iron or tin put into water with the blue prussiate produce the same effect. The oxygen partly separates from the oxyd, and is transferred to the metal. A similar phenomenon occurs in the formation of sweet mercury, *mercurius dulcis*, by the mixture of corrosive sublimate with mercury.

M. Proust confounds the denominations of the red and yellow oxyds, because they are both saturated with oxygen. But whatever acid is employed to dissolve the red oxyd, it always yields a yellow precipitate by means of pure alkali.

From all these facts we may conclude that when an infusion or tincture of galls is mixed with a solution of green sulphate, there is only one portion of the green sulphate which produces a black colour, while the remainder whitens or bleaches. Hence it appears

to result: 1. that solutions of iron are improved by time, provided that the oxydation be uniformly kept up by the contact of air; 2. that dyes and inks grow black by exposure to air.

It will be seen in the sequel, that I have applied this principle with advantage to all the operations in which iron is employed. It is sufficient at present to observe, that by calcining the green sulphate to redness, and by dissolving the residuum, effects are produced very superior to those obtained from the employment of the sulphate sold in the shops.

Besides the green and red oxyds, which are found in the different combinations of iron with the sulphuric acid, M. Thenard has also discovered in them a white oxyd. It is obtained by decomposing the sulphate by a caustic alkali, on the addition of which there instantly appears a white precipitate, which quickly assumes a green colour, but eventually becomes red.

According to M. Thenard, this white oxyd, saturated with sulphuric acid, constitutes the greatest part of the sulphate of iron sold in the

shops. Nevertheless, this oxyd, when it is united with a small excess of acid, yields a sulphate the colour of which is a clear emerald-green, instead of the deep bottle-green, characterising that which, in commerce, is held in the highest estimation.

The sulphates may contain iron in these three different states; the characters belonging to each of which we shall proceed to point out

The *sulphate of the white oxyd* is formed when the iron is treated with sulphuric acid.

When the saturation is perfect, this sulphate is of a bottle-green; it is this colour which is most esteemed in commerce. It effloresces and falls down into a white powder, decomposes the oxy-muriatic acid, and the oxyd changes to a green or red colour.

The saturated *sulphate of the green oxyd* does not crystallize; it absorbs oxygen from the atmosphere, deposits a neutral yellow and highly oxydized sulphate of a red colour, though its oxyd be green. The muriatic acid oxygenizes the oxyd to its *maximum*, and the iron again reduces it to the state of the white

oxyd. When combined with a superabundant acid it loses its red colour; it then assumes the form of crystals, which approach in colour to an emerald-green; they neither effloresce, nor are they subject to deliquescence.

By treating the red oxyd with the sulphuric acid we obtain its sulphate; this sulphate throws down a yellow precipitate from the solutions of the sulphate of the white and green oxyds.

When saturated, this sulphate is always of a yellow colour.

These three sulphates may contain a superabundant acid which modify their properties.

The oxyd of iron requires for its saturation a quantity of acid so much stronger, as it is more oxydized. It possesses this property, in common with all the other metallic oxyds.

In pursuing this subject we shall follow the same method as when treating of alum, and consider it under the two separate heads of native and artificial sulphate.

ARTICLE I.

Of Artificial Sulphate.

Almost all the sulphate of iron employed in the arts, is procured from the decomposition of martial pyrites.

The nature of these pyrites varies, not only in regard to their mixture with other earthy, metallic, or bituminous matters, but especially with regard to the proportions in which the sulphur and iron are combined with them.

Pyrites displays all the intermediate shades of yellow, from a grey to a deep golden colour.

Pyrites moreover appears under a great variety of forms; frequently it is found disposed in marly, schistous, and other clays, in more or less regular cubes of different sizes. They are sometimes found of a spherical form, and in this case they are composed of many small pyramids, the points of which all unite in the centre of the mass; these pyramids are often terminated at the circumference by very short

pyramids, commonly of a tetrahedral form, and having their bases joined to those of the first.

Pyrites sometimes exists in large masses, forming strata frequently of a considerable extent. When found in this state, it possesses much hardness, and strikes fire with steel. Its colour though sometimes brilliant, and of a lively yellow, is yet more frequently dull; its fracture very often displays veins or yellow points of greater brilliancy than the rest of the mass. It is not unusual to find pyrites of a very dark fawn-colour. In its fracture it often exhibits many different shades of colour; it is sometimes studded over with large black spots; this kind is in general readily decomposed. It is also found intermixed with earths, bitumens, and rocks, which are then characterized by the appellation of pyritous substances. The extreme division of the pyrites, when under this last form, by facilitating the action of the air and water, hastens its decomposition.

According to the various states in which pyritous substances are found, they are more or less susceptible of decomposition, or *vitriolization*. In general this process is more diffi-

cult and tedious in proportion to the quantity of sulphur they contain. I have uniformly observed that the spherical pyrites is more readily vitriolized than the cubical; that among the former, those whose surface is rough, are more refractory than others whose surface is smooth; that those which are of a striated texture, effloresce more rapidly, and that the pyrites disseminated in pitcoal and other bituminous matters is more easily decomposed than that which is formed in masses of hard stone.

But whatever be the nature of the pyrites, the sulphate is never found ready formed in the mass, till it has undergone decomposition. This fact, which the modern doctrine of *vitriolization* has rendered unquestionable, had been known and confirmed by the numerous experiments of Henckel.

The formation of the sulphate depends then essentially on the decomposition of the pyrites; and it is this decomposition which is termed *efflorescence, vitriolization,* &c.

SECTION I.

Of Vitriolization.

Vitriolization cannot occur without the aid of air, or of a body which, by its decomposition, may supply the pyrites with oxygen.

Henckel long ago irrefragably proved that the presence of air was necessary to this process ; he even affirmed, that the air enters into combination with the pyritic matter, *non ut instrumentum transiens, sed ut immanens.*

This assertion which, considering the time when it was made, may be viewed as extremely bold, has of late received the most ample confirmation.

The whole art of vitriolization consists, therefore, in employing the most suitable means for converting sulphur into sulphuric acid, and to facilitate, in this way, the formation of the sulphate of iron. The processes employed in different manufactures, to answer this end, are variously modified according to the nature of the mineral. But as my object is not so much to detail different pro-

cesses as to point out the principles on which they depend, I shall here divide pyrites into three kinds. I have confined myself to this small number from a conviction that all the methods employed in our manufactures may be referred to one or other of these divisions.

1. Pyrites with an excess of sulphur.

2. Pyrites in which sulphur and iron are contained in due proportions.

3. Pyrites impregnated with bituminous matters.

1. When the sulphur is superabundant in the pyrites, it tends to prevent the oxydation of the iron, and the vitriolization or efflorescence either does not occur, or proceeds very slowly. In this case a portion of the sulphur must first be separated by the distillation or roasting of the mineral, as has already been shewn under the article sulphur, after which we proceed to the vitriolization of the scoriæ or residuum.

For the most part it is reckoned sufficient to expose to the action of the air the residuum of the distillation or roasting, and while the

vitriolization continues, to water it occasionally, with the view of facilitating the efflorescence. In proportion as the copperas is formed, it is washed off by the waters, and deposited in basins, wherein it is allowed to remain, till it is transferred into the evaporating pans.

At Dilta, in Nericia, a province of Sweden, after separating the sulphur, on which account alone the pyrites is wrought, the residuum is vitriolized to procure the copperas.

At Schwartzemberg, in Upper Saxony, the residua of the distillation are left exposed to the air during two years, after which they are twice or thrice lixiviated, to effect the solution of the copperas.

In the duchies of Liege and Limberg, the vitriolization is accomplished either by leaving the pyrites to spontaneous decomposition, or by collecting the crude pyrites in heaps, in the middle of which an empty space is left, into which are thrown the residua of the distillation, red hot from the cylinders. This stratum of inflamed pyrites is covered with the crude mineral, and the mass left to heat, and fall into decomposition.

2. When the sulphur does not superabound, the distillation is superfluous. In this case, if the pyrites be hard, and difficult of efflorescence, it is previously calcined to render it susceptible of vitriolization.

In some works the pyrites is stratified with the fuel. In this way the mass is sometimes raised to the height of twenty feet by forty feet in length. The fire is applied to the pile in many points at once; but as it spreads slowly, seven or eight days usually elapse before the calcination is completed. The pyrites is afterwards left to effloresce, and occasionally moistened to hasten the decomposition. This method, we are informed by Monnet, is pursued in many establishments, such as in those of Leige and Limberg.

At Geyer, in Upper Saxony, the pyrites is subjected to calcination during fifteen days.

In no case ought the roasting to be pushed to too great a length, as a double inconvenience would thence result, since thus not only would a portion of the sulphur be dissipated, but likewise the copperas, which is formed during the calcination, be decomposed.

Hence we should confine our efforts to fa-

vour the process of vitriolization, and leave to the agency of time to produce an accurate combination of the different principles.

There are many kinds of pyrites which effloresce so readily, as to supersede the necessity of calcination. Of this nature are the kinds of pyrites wrought at Newcastle upon Tyne, at Alais in France, &c. At these different places, after the pyritous mineral is extracted from the mine, it is left to effloresce.

The process of vitriolization is extremely simple. Beds or strata, from three to four feet in height, are formed with fragments of the mineral, as they are drawn from the mine. The ground on which these beds are raised ought to be firm, and impervious to water. It should also form an inclined plane, in order to favour the efflux of the waters of lixiviation into trenches, or furrows cut for its reception, and uniting in one common reservoir.

In this manner, after the pyrites is decomposed, and the saline matter dissolved by the waters, it is carried into the common reservoir.

In proportion as the decomposition proceeds, the pyritous matter becomes heated;

and in order to keep up this heat, the mass is occasionally watered, particularly when the air is dry and warm.

When the first water of lixiviation is not sufficiently impregnated, a circumstance which may readily occur after much rain, it is affused anew upon the mineral.

Nothing is more essential to the success of works of this kind, in which the process of vitriolization is left to the agency of nature, than to accumulate the pyritous mineral in extensive heaps, and to expose as large a surface of it as possible to the combined action of air and water, in order that the waters of lixiviation may be richly impregnated, and yield an ample product of copperas.

These beds continue long to be productive, and are only exhausted after a lapse of many years. When the pyrites is pure, very little residuum is left behind.

If the vitriolization diminish, the stratum must be turned, and again exposed. It is only, however, in this case, that such a step should be taken, for if the efflorescence be going on, it would only tend to retard its progress.

On the British coast, and the opposite one

of France, is found rounded pyrites, extremely susceptible of efflorescence, and yielding copperas of an excellent quality. I have seen at Honfleur a manufactory of copperas, which is procured from a pyrites of this nature, collected from among the pebbles thrown out by the sea.

Some blackish earths contain pyrites in minute grains, which are decomposed with the greatest facility. This kind of ferruginous earth abounds in alumine, and yields, by vitriolization, the sulphates of iron and alumine. A similar species of earth is wrought at Cremnitz, in Hungary, and Baurin in Picardy, in France.

3. Pyrites is also very often found in pit-coal, and other bituminous matters, though it is not present, in equal abundance, in all of them. In some, the sulphur is scarcely perceptible, while others exhale so strong a sulphureous odour during combustion, as scarcely to be supportable. These last, when exposed to the air, are so susceptible of decomposition, that they frequently take fire, and burn violently.

The efflorescence of the different species of pit-coal, and other bituminous substances, does not uniformly yield the same products. Sometimes the alumine predominates, in which case alum is principally produced; when, on the contrary, the iron superabounds, the sulphate of iron is the chief product. Frequently the alumine and iron are found united in these kinds of pyrites.

The inferior mines of pit-coal, characterised by the appellation of *pyritous* or *sulphureous*, are merely wrought for the sake of the alum or vitriol contained in them. The nature of this coal is easily detected by the sulphureous odour it exhales during combustion, from the existence of pyritic veins in its strata, and especially from its want of consistence, and the property it possesses of falling into powder on exposure to the air. Other characteristic marks of this species of coal may be taken from its becoming heated when amassed together in a heap, from its injurious action upon copper or iron vessels, from its being unfit for the forge, or as a flux for metals, which it renders brittle, and from its being covered with saline

efflorescences, the analysis of which shews to what purposes this pyritous substance may be most advantageously applied.

In the Beauvoisis, the pyritous pit-coal is wrought in order to procure copper; it is first exposed to the air for a short time, in which situation it very speedily effloresces, when it is removed beneath sheds, and disposed in thin beds, until its lixiviation be completed.

In several parts of Picardy, and Soissonnois, are found strata of a pyritous black earth, vulgarly known under the name of *coal-earth*. This earth is decomposed on being brought into contact with the air; it becomes heated and takes fire, and the residuum of this combustion may be advantageously employed as a manure.

These beds are usually incumbent on argillaceous strata, and covered with an excellent friable, and ochreous mould. Several copperas works have been already established in the neighbourhood of these pyritic beds. The vitriolization of this kind of mineral is performed with some difficulty, owing to its aptitude to take fire when collected together in a large heap.

It should seem that pyritous strata have been formerly more abundant than at present, since our globe every where exhibits traces of their decomposition.

Ochreous earths, and volcanic remains attest their early existence, while our warm springs and burning mountains sufficiently prove, that there are still contained in the interior of the earth extensive beds of pyrites in a state of decomposition.

§ II.

On the Lixiviation of Vitriolized Pyrites.

When vitriol is formed by the decomposition of the pyrites, it requires to be extracted, and this operation is termed the *washing* or *lixiviation* of pyrites.

It has been already observed, that when pyrites is decomposed in the open air, formed into beds upon the ground, the lixiviation is spontaneously performed by rain water.

In vitriol works, ditches or reservoirs are formed, in order to contain the pyrites, which

is covered with water during the space of twenty-four hours, after which it is poured into a common reservoir, and allowed to depurate before being removed into the evaporating caldrons.

When the mineral does not contain much vitriol, it is necessary to pour the same water upon several beds successively, in order that it may become more completely saturated.

In most of these establishments the waters of lixiviation are conducted into reservoirs, where they begin to deposit the ochre and other extraneous bodies suspended in them, after which they are removed into a common reservoir, in which they become still further depurated; and it is from this last reservoir that the evaporating vessels are supplied.

The evaporation is generally performed in leaden caldrons, which vary in their capacities in different manufactures. M. Jars saw them in England of five metres (16 feet English) in length, by 4 metres (13 feet English) in width. These enormous vessels are placed upon plates of cast iron, which are supported in their turn by strong arches of brick-work; and the fire-place is constructed exactly in the middle.

The most general size of these caldrons is only however, one metre (from 3 to 4 feet English) in length, by two metres (from 6 to 7) in width, and three metres (from 9 to 10) in length. They are set upon strong iron bars covered with very thick plates of sheet iron, in order to prevent them from sinking at the empty spaces left between the iron bars.

The lixivium from the common reservoir is usually carried to the caldron by means of a small pipe communicating from the one to the other; and in this way likewise the waste occasioned by evaporation is easily supplied, and the liquor preserved at the same height during the process of boiling.

The evaporation is continued till a pellicle is formed on the surface of the liquor; but if the concentration be carried beyond the 40th or 41st degrees of Beaumé's arcometer, it becomes turbid, and throws down a white precipitate which attaches itself to the bottom of the caldrons, and greatly injures them.

After withdrawing the fire, the liquor is left to settle for a few hours, and then drawn off into the crystallizing vessels. At the termination of eight or ten days, the crystals which

are formed are removed, and the *mother waters* are allowed to drain off.

In all these establishments, the lixivium is mixed with a portion of the mother water; but in some of them this is done at the beginning of the boiling process, while in others it is delayed until towards its conclusion, and this last method appears to me to be attended with the greatest advantage.

In England, and other countries, pieces of old iron are thrown into the caldron in which the liquor is boiled, with the view of saturating the superabundant sulphuric acid, which is generally present in the lixivium, as well as decomposing the small portion of sulphate of copper, from which the mineral is not always wholly free.

Square wooden vessels 0,650 metre (nearly 3 feet English) in length, and the same in depth, are frequently employed for the purpose of crystallization; but sometimes they are constructed of mason work, and the surface covered with a good varnish; casks or vats are also sometimes used for this purpose, as they can be easily moved when the mother waters are to be drawn off.

Thorns, or sticks placed cross-wise, are frequently disposed in the crystallizing vessels, with the view of favouring the crystallization.

It has been already mentioned, that when the evaporation is carried beyond 40 or 41 degrees of Beaumé's areometer, the liquor becomes turbid, and throws down a white powder, which acquires the consistence of plaster, and is detached with much difficulty from the bottom of the caldron. This deposition more readily takes place when the liquor is acid than when it is duly saturated.

In all cases, as soon as the deposition is formed, the liquor is so much weakened as to lose from 5 to 6 degrees of concentration; it recovers its green colour, and the evaporation may be continued to the same degree as formerly, when a similar deposition takes place, and is followed by an equal diminution in the strength of the fluid. Thus by a repetition of this process, the whole of the sulphate dissolved in the lixivium may be converted into a whitish precipitate.

On analysing this precipitate I found it to be a sulphate deprived of its water of crystal-

lization, and nearly resembling that which is obtained by depriving the green sulphate of its colour by means of heat.

I distilled separately equal parts of the green and white sulphates; the first yielded the usual quantity of water of crystallization, but none was furnished by the second.

I dissolved the white sulphate in the water obtained from the distillation of the green sulphate, by which means it was converted into a green sulphate.

The precipitate in question is therefore a white sulphate destitute of the water of crystallization.

It appears then, that when the waters of lixiviation have been brought to that degree of concentration that a sufficient quantity of water is not left to supply the water of crystallization to the whole sulphate contained in the bath, a portion of it is precipitated in the form of dry sulphate; it is even probable that the different degrees of oxydation in which the iron is found in the solution, concurs to produce this phenomenon, and that the greater or less solubility of the sulphates, according to this

degree of oxydation, occasions the precipitation of one portion before the other.

ARTICLE II.

Of the Artificial Sulphate.

Copperas is manufactured in the same manner as alum.

Several works of this kind are established at Paris, Rouen, and Montpelier.

The methods by which the artificial sulphate of iron is procured, may be divided into two kinds.

The first consists in the formation of artificial pyrites, which is afterwards subjected to the process of vitriolization.

The second has for its object the direct combination of the sulphuric acid with the iron.

1. Artificial pyrites is formed by carefully mixing equal parts of filings of iron and sulphur, and afterwards moistening them with a sufficient quantity of water to form a paste

This mixture becomes heated, swells up and inflames; it is known under the name of *Lemery's volcano*, because that chemist appears to have been the first who devised this experiment.

When this method is employed in copperas works, it is necessary to avoid inflammation, as it partly decomposes the sulphate, which may be easily done by occasionally stirring and turning over the mass, whenever the heat becomes so great as to appear ready to burst out into a flame.

I have myself formed very beautiful sulphate in this manner, employing however a less proportion of sulphur; but I uniformly observed that a considerable quantity of ochre was produced, which escaped from the combination, and which appeared to me from the result of several experiments to be in proportion of one fourth of the iron employed.

I have also used in my experiments on vitriolization, sulphurets of iron produced directly by the action of fire; but I have uniformly found their decomposition to be extremely tedious and difficult, so that the mixture appeared to me to be greatly preferable.

2. The preparations of sulphuric acid has attained to such a degree of perfection, and works of this kind have lately become so numerous, that the consumption of the acid falls greatly short of the quantity prepared, which has induced the manufacturers of this acid to turn their attention to its combination with alumine, or iron, in order to form alum, or copperas.

The solution of iron in the acid is performed in several different ways.

A. By pouring diluted sulphuric acid into a cauldron, adding to it a sufficient quantity of iron. In this way the solution is gradually accomplished, a copious precipitation ensues, and the liquid almost entirely disappears toward the end of the process. This precipitate is formed into beds, and occasionally turned, until it be sufficiently lixiviated to form copperas.

B. By pouring one part of concentrated sulphuric acid into three parts of water, and dissolving iron in this mixture, until it be completely saturated.

C. By taking the water, concentrated to 35 degrees, from the chambers or receptacles,

wherein sulphuric acid is prepared by burning sulphur, and saturated with iron.

In all these cases, it is necessary to employ towards the end of the process, the iron in a very divided form, as in that of filings, for example, or otherwise it will be difficult completely to saturate the acid.

Cast iron dissolves with greater difficulty than forged iron.

As the evaporation and crystallization do not require any particular process, we shall not here enter into any detail concerning them.

SECTION VII.

On the Combinations of Sulphuric Acid with Copper.

The sulphate of copper, termed *blue vitriol, Cyprus vitriol,* &c. though less extensively employed than either alum, or sulphate of iron, is nevertheless so much used as to merit a particular place in this work.

It is of a blue colour, which is unchangeable by the action of the air.

It readily crystallizes, and the usual form of the crystals is that of rhomboidal parallelopipeds.

It is of an astringent and somewhat metallic taste; melts in the fire, loses its water of crystallization, and falls down into a bluish white powder.

It swells up with a bubbling noise on being first exposed to the action of the blowpipe, but afterwards subsides and remains at rest; the metal is reduced when placed in contact with charcoal.

It readily dissolves in water, to which it imparts a blue colour. Four parts of this fluid dissolve one of the sulphate of copper, at 60 degrees of Fahrenheit's thermometer.

Ammonia precipitates the oxyd of copper of a blueish white colour; but when added in excess, the liquor assumes a most beautiful blue colour, by the solution of the precipitated oxyd.

Iron precipitates the copper in a metallic state; this may be exemplified by merely rubbing one of the crystals of blue vitriol on the blade of a knife, when the copper instantly lays hold of the iron, especially if the sur-

face of the crystal has been previously moistened.

Its specific weight is to that of water as 2,23 to 1.

It is composed of 0,27 copper,
0,30 acid,
0,43 water.

The different processes employed in the extraction or formation of the sulphate of copper, may be reduced to four.

1. The vitriolization of cupreous pyrites.
2. The evaporation of cupreous waters.
3. The formation and vitriolization of artificial pyrites.
4. The solution of copper, by the sulphuric acid.

1. The cupreous pyrites is distinguishable from the martial pyrites by the greater brilliancy of its colour. The former is besides generally found, according to the observation of Henckel, at a greater depth below the surface of the earth than the latter.

The same chemist has discovered it in the proportion of 50 pounds of copper to the quintal.

This kind of pyrites is less susceptible of vitriolization than the other; the existence, however, of cupreous springs, and the examination of sulphureous copper mines, leave no doubt respecting its spontaneous decomposition in the bowels of the earth.

In order to decompose the pyrites, preparatory to vitriolization, it is stratified with thin beds of combustible substances, which are set on fire. It is, however necessary, that the heat thus produced be not too great, as the process is much better performed, when the heat is moderate and long continued.

At Marienburg, where a sulphureous tin mine mixed with copper is wrought, they roast the mineral during ten or twelve hours in a reverberatory furnace, brought to a red heat; after the fire is withdrawn, they continue to turn over the mineral, until the furnace loses its red heat, when it is taken out, and thrown into a copper full of water, in which it is agitated for some time. When the water is sufficiently saturated, they next proceed to eva-

poration, in order to extract the sulphate dissolved in it. Much of this pyrites does not yield a sufficient portion of copper to compensate the expence of its extraction; it is nevertheless, sometimes wrought in order to procure the sulphur and vitriol, by means of the simple processes described under the article *sulphur*.

2. The vitriolization of cupreous pyrites, in the interior of the earth, is sufficiently proved by the nature of several springs, the waters of which are so much loaded with vitriol of copper, that it proves a profitable speculation to extract it. This is done by throwing into the water pieces of old iron, in order to precipitate the copper, which takes the place of the iron in proportion as this metal displaces the copper from its combination with the sulphuric acid. The copper thus obtained is known in France by the name of *copper of cementation*.

In the mines of Neussol, in Hungary, at the depth of 116 metres, (377 feet English) are placed at different distances, several vats in order to collect the cupreous waters, which flow into them through a kind of gallery

above; and it is from these waters that the metal is separated by means of the process we have described.

In the mines of Graslitz, in Bohemia, of Smolnitz, at the foot of the Crapac mountains, at Altemberg, at Rammelsberg, and other places; similar methods are employed for procuring the copper.

When the copper is precipitated by iron, the sulphate of iron which is formed, might be extracted by evaporation, but is in too small a quantity to defray the expence of this process.

3. In the principal blue vitriol manufactures established in France, the operations are carried on in the following manner.

The copper, intended for vitriolization is first dipt into water, and its surface, while still wet, covered with a stratum of powdered sulphur. The copper plates thus prepared are put into an oven heated to redness; after some time they are taken out, and while yet hot, plunged into a copper filled with water; and these operations are repeated several times successively, until the whole is converted into vitriol. By degrees, the water becomes

loaded with the sulphate, and when completely saturated, it is concentrated, in order to extract the vitriol.

The following are the results of several experiments which I myself have made, in order still further to simplify the process.

I fused one kilogramme (2 lb. 3 oz. 5 dr. avoirdupois, of sulphur) in a crucible heated to redness, into which I introduced an equal weight of sheet copper, taking care to keep up the same degree of heat. In a short time a flame began to ascend, through which the red hot copper could be perceived. As soon as the flame ceased, I removed the crucible, and after allowing it to cool, I found the plates of copper very brittle, of a beautiful dark red colour, and of a striated glossy fracture. They weighed 12,84948 hectogrammes ; 2 lb. 5 oz. 01552 avoirdupois.

I pounded, and divided this sulphuret into two parts, one of which I moistened with pure water, and the other with diluted sulphuric acid. The first did not effloresce, and notwithstanding every attention on my part, at the end of thirteen months, not the smallest appearance of vitriolization had taken place;

the second effloresced; and by sprinkling it occasionally with acidulated water, I extracted from it 2 kilogrammes, (4 lb. 6 oz. and 10 dr. avoirdupois) of vitriol.

It produces a considerable saving of sulphur, to throw it on the heated copper; by this means the copper becomes also very brittle, its fracture is of a blueish red, and it is easily acted on by sulphuric acid.

4. Sulphuric acid does not act upon copper at a low temperature, but when digested togegether with an intense heat, a part of it is decomposed; much sulphureous acid is exhaled, and the residuum is a white paste, readily soluble in water, which yields on evaporation, beautiful crystals of vitriol. The action of the sulphuric acid is much assisted by oxydizing the metal, by the nitric acid, which is employed with it.

A solution of nitrate of copper, boiled with sulphate of potash, produces beautiful crystals of sulphate of copper.

Bell metal, pounded and digested with sulphuric acid, in a sand bath, is reduced to a white powder, which is an oxyd of copper;

the super-natant liquor is of a blue colour, and yields sulphate of copper.

SECTION VIII.

On the Combinations of Sulphuric Acid with Zinc.

Besides the sulphates of iron and copper, the sulphate of zinc also furnishes an article of commerce. It is likewise termed *white vitriol,* or *vitriol of Goslar,* and is distinguished from all other salts by the following characters:

Colour of a dirty-white, becoming yellow, when long kept.

Fracture grained.

Taste styptic.

Soluble in about 2 parts of water, at 60 degrees of Fahrenheit. Crystallizes in tetrahedral prisms, terminated by four-sided pyramids.

It loses a part of its acid by heat; before the blow-pipe it instantly swells up with a crackling noise, it then falls down, and when treated with charcoal the metal is reduced; it

inflames and exhibits all the phenomena which accompany the combustion of zinc. The proportions of its constituent principles are in the following order :

Bergmann.	Kirwan.
40	20,5 acid,
20	40,0 oxyd,
40	39,5 water.

M. Tennant found contained in this sulphate, when dried, 50 acid and 50 oxyd.

Its specific weight in relation to water, is as 2 to 1 according to Kirwan, and as 19 to 10 according to Brisson.

The sulphate of zinc is furnished by the decomposition of blend, or native sulphuret of zinc. This mineral is very common, and frequently found mingled with, or lying by the side of galena, or sulphuret of lead; its presence frequently imposes on miners respecting the abundance of the true mineral. But although the sulphuret of zinc be common, the sulphate is extremely rare, which may readily be accounted for from the difficulty with which the mineral is vitriolized. It is, however, pre-

sent in some mineral waters in Sweden, as we learn from the analysis of them by the celebrated Bergmann; and mineralogists have had several times occasion to observe it in different mines.

Every species of blend cannot, however, be vitriolized in the same manner as those of Rammelsberg, which is subjected to this process in the founderies of Goslar. This last contains zinc, copper, and lead, mineralized by sulphur.

Here the mineral is roasted, and thrown while red hot into a vessel filled with water, in which it is allowed to remain during eighteen hours. This process is repeated several times, and after the solution has become clear, it is removed into leaden caldrons and evaporated, in order to produce the crystallization of the salt.

The crystals are melted in a copper caldron, and the surface of the solution skimmed with a hair sieve; it is then poured into a wooden vessel, and constantly stirred until it becomes cool, and acquires a sufficient degree of consistence, when it is formed into loaves for the

purpose of sale; and in this state has the appearance and colour of refined sugar.

I have myself extracted, by a similar process, a large quantity of the sulphate of zinc from the blend of St. Sauveur, in the department of Lozere.

The sulphate of zinc may be easily formed by dissolving the metal in diluted sulphuric acid. During the progress of the solution, which is performed with great facility, a considerable quantity of hydrogen gas is disengaged, by the decomposition of the water in contact with the metal.

CHAPTER X.

On the Combinations of the Nitric Acid.

OF all the combinations of the nitric acid, the only one employed in the arts is the *nitrate of potash.*

SECTION I.

On the Combinations of the Nitric Acid with Potash.

The nitrate of potash, called likewise *nitre, saltpetre,* and *salt of nitre,* is distinguished by the following properties.

It usually shoots in crystals, which are six-sided prisms, terminated by six-sided pyramids.

Its specific weight is to that of water as

19,369 to 10,000. It is of a pungent taste, leaving a sensation of coolness in the mouth.

It is very brittle.

It is soluble in seven times its weight of water at 60 degrees of Fahrenheit, and in an equal weight at 212.

It is permanent in the atmosphere.

It melts on exposure to an intense heat, giving out at first oxygen, and when it has attained a white heat, azote.

Mixed with combustible substances, and exposed to the fire it fuses, and the acid is decomposed, exhibiting all the phenomena of the most rapid combustion.

Its constituent principles are, according to

Bergmann.	Kirwan.
31	44,0 acid,
61	51,8 potash,
8	4,2 water.

The extensive use of saltpetre in the arts, as well as its forming the base of the constituent principles of gun-powder, renders a knowledge of it equally important as interesting.

These circumstances have led us to consider

separately, the formation, extraction, refinement, and uses of this salt.

Saltpetre is daily produced in different situations.

It is more particularly found near our habitations, and in places impregnated with the products of animal or vegetable decomposition.

It is not produced in any considerable quantity in very dry situations exposed to the sun, but neither is it found in more abundance in dark subterranean caverns.

Shallow excavations into which the light does not fully penetrate, are more favourable to the production of saltpetre.

Narrow streets in which the houses are so high as to exclude the sun, produce the greatest quantity of this salt.

Very porous calcareous earths, especially when slightly ochreous, are most favourable to nitrification.

According to the experiments of M. la Rochefoucault, chalk mixed with a small portion of alumine, will produce a greater quantity of saltpetre than when perfectly pure.

Either too warm or too cold a temperature

are equally unfavourable to the formation of this salt.

It abounds most in places exposed to the north, and at the bottom of walls, near the ground.

Most of the saltpetre found in plaster, chalk, marles, and gravelly earth, has a calcareous base, while that which is produced in sheep-folds, coach-houses, and stables has a base of potash. Such are the results of numerous experiments.

It now only remains for us to shew the consonance of these facts with the principles of science, and to deduce from them consequences proper to direct us in the manufacture of saltpetre.

Nitrate of potash is formed by the combination of nitric acid with potash, and the nitric acid itself is composed of azote and oxygen.

The art of forming saltpetre consists then in ascertaining the particular circumstances under which this combination takes place, and the means of producing it.

Azote and oxygen in a gaseous state can only be combined by means of the electric

spark; but it appears, that it is principally the azotic gas which resists the combination, since the oxygen assumes a concrete form with great facility, on a suitable base being presented to it.

In order to produce the combination of these two gases, it is then necessary to collect the azote, during its disengagement from its combinations, or, in other words, before it loses its elastic or expansive power, as in this state it most readily unites with oxygen.

The decomposition of vegetable and animal matters affords it in this state, since it forms one of their constituent principles, and in proportion as it is disengaged by their disorganization, it is seized by the oxygen and hydrogen; with the first it forms nitric acid, and with the second ammonia.

When vegetable principles are disengaged in situations excluded from air and light, as for example, under the floors of dwelling houses, or hay lofts, the substance thus formed only requires the contact of air in order to produce saltpetre.

This mould, like that of pyritous earths, does not effloresce but on exposure to the influence

of the atmosphere; and we may consider that which is formed in places where air and light cannot enter, as a kind of *nitrous turf*. I have given the name of *nitrification* to the decomposition of this mould, in order to approximate it to a similar phenomenon, which is exhibited by the *vitriolization* of pyritous turfs.

This leading idea, respecting the production of saltpetre by the *nitrification* of the mould, ought never to be lost sight of in our endeavours to discover the most proper methods of accelerating the formation of this salt.

From numerous and repeated experiments, it seems now universally agreed that calcareous or chalky earths are most proper for this purpose, as nitrification is produced in them with the greatest rapidity. But as these earths present only a base for the nitric acid, it is necessary either that they be impregnated with substances which may supply its principles, or that they be exposed to its emanations. Thus a mixture of animal and vegetable matters, exposed at a proper temperature to the action of light, form excellent nitrous earth.

It should seem, that in order to prepare ani-

mal and vegetable matters for nitrification, it is proper to disunite their principles by screening them from light, and by exposing them afterwards to the action of the air, by which the combination of the azote with the oxygen is produced, and forms an acid which unites with the earthy and alkaline bases found in the mixture.

It follows also, from what has been said, that all plants are not equally adapted to the purpose of nitrification, since they do not all contain azote in the same proportion.

Poisonous plants, and those which emit a strong or fetid odour, appear the most suitable; such as hemlock, tobacco, henbane, cabbage, horehound, &c. the extracts of which when long kept, it has even been observed, become covered with nitrous crystals.

The same observation holds equally true with regard to animal substances, all of which are equally applicable to the process of nitrification.

The remains of herbivorous animals are preferred to those of carnivorous ones, as the emanations from the former became more quickly nitrified than those of the latter.

Among the parts belonging to animal bodies the blood is of all the humours that which is the most favourable to nitrification.

Urine concurs to produce much muriate.

The soft parts are preferable to those of a harder and more firm texture.

In all countries where a sufficiency of saltpetre is not naturally supplied to answer the demands of society, this salt is formed by means of nitre beds.

In Prussia, five measures of black vegetable earth, or that taken from caverns, or other subterranean places, are mixed with a measure of lixiviated ashes and barley-straw; after impregnating these matters with the water of dunghills, they are formed into banks 20 feet long, by from 6 to 7 in height. Sticks are put into the stratum, and withdrawn when it has attained sufficient consistency.

These walls or banks are formed in moist situations, sheltered from the sun, and covered with a roof of straw. They are occasionally watered in order to terminate the lixiviation by the end of the year.

At Malta, they employ for this purpose the most porous calcareous earths, and mix them

with wet straw. This they form into oblong triangular piles, with alternate strata of earth and dung, and water them with a mixture of the mother water of saltpetre, urine, and water of dunghills.

After allowing the surfaces of these piles to become dry, they are broken down, turned over, and watered anew. When the dung is decomposed it is replaced by a mixture of water and dung.

The heap is kept moist by watering it occasionally during the course of three years; and during the first year it is sprinkled over once a month with slaked lime.

In Sweden they form saltpetre beds with stubble, lime, ashes, and meadow earth. The foundation is constructed with bricks set in the ground; on this base is placed a bed of mortar made with meadow earth, ashes, lime, and a sufficient quantity of urine or the mother water of saltpetre. To this succeeds a bed of stubble, and over this are alternately placed layers of stubble and mortar.

The beds are preserved from the influence of rain by means of boards and a covering of

heat. They are occasionally moistened with urine, stagnant waters, &c.

These beds prove productive from one to ten years.

The saltpetre is detached from these beds by means of brooms every eight days; they water them as soon as they are cleared of the salt, with the mother waters diluted with pure water.

The residuum, at the termination of ten years, affords an excellent manure for the culture of hemp and flax.

In the canton of Appenzell, in Switzerland, they have availed themselves of the situation of the stables, on the declivity of the mountains, to form in them very productive nitre beds.

These square stables are supported on one side by the mountain itself, while the opposite side is raised upon stones, leaving an open space between the floor and the ground. In this space trenches are dug, three feet in depth, into which are thrown porous earths proper for nitrification, and which readily becomes impregnated with the urine of the cattle as it

flows into them. This earth is lixiviated every two or three years. The lixiviated residuum is dried and returned into the trenches.

A stable of a moderate size commonly yields one thousand weight of saltpetre.

The opening of these nitre beds is directed towards the north.

ARTICLE II.

On the Lixiviation of Nitrified Earths.

Previous to employing any earth for the extraction of saltpetre, we ought to ascertain whether it contains this salt in a sufficient quantity to compensate the expence of preparing it.

The manufacturer is guided in his judgment respecting this circumstance, by inspecting, and tasting the earths, in which it is supposed to be contained.

Stony substances impregnated with saltpetre, crack and effloresce. Neither mosses

nor other plants are ever observed to vegetate on their surfaces or in their fissures.

When particles of earth containing saltpetre, are introduced into the mouth, they impart a saline taste, according as the base of the salt consists of an earth or an alkali, and according to the nature and properties of the different saline matters intermingled with them. When any earth is discovered to contain saltpetre in a sufficient quantity to render its extraction profitable, holes are dug into the soil of such a depth as to enable us to form a correct judgment respecting the thickness of the stratum, and the propriety of working it.

After carefully removing the earth, it is left exposed to the air before proceeding to subsequent operations.

To lixiviate the earth, casks, or stone basins are employed; these basins are perforated with a small hole, into which is introduced a funnel, closed with a peg. In this opening, on the inside, is placed a wisp of straw or hay, in order that the waters may, by filtering through it, be rendered free of all impurities.

When the cask is thus disposed, it is filled with the earth to be lixiviated to within two

or three fingers' breadth of its superior edge. The funnel is closed, and water poured on the materials till they float; they are then left to settle for four or five hours; after which the funnel is opened, and the water which flows out is received into a shallow tub, placed beneath the cask.

This first water is not yet sufficiently impregnated with saltpetre to be evaporated with advantage. The earth itself is not, however, exhausted of its salt, and hence the custom of pouring the same water upon three different parcels of earths; one of which has been subjected to two lixiviations, the other to one, while the third has not undergone this process.

As saltpetre is for the most part combined with an earthy base, and as it is of importance to reduce it to the state of nitrate of potash, as much with the view of facilitating the crystallization, as to augment the product, pure potash is employed either mixed or combined with other bodies.

Some manufacturers mix the saltpetre earths with ashes; others form a layer of ashes at the bottom of the casks, in which the lixivia-

tion is performed; some boil the ashes with water of the first boiling; while others mix the lixivium of the ashes with that of the earths.

Some saltpetre-makers employ brine, others potash, while many at present use the sulphate of potash, which is furnished in abundance by the residua left from the combustion of the sulphur and saltpetre employed in the preparation of oil of vitriol, in the same manner as by the residuum from the decomposition of the nitrate of potash by the sulphuric acid.

This process merits some consideration; the sulphate of potash is carefully lixiviated, and concentrated to 20 degrees. For this purpose a deep vessel is filled with three quarts of the lixivium concentrated to 20 degrees by the mixture of a small portion of mother water; and after adding to it a fifth by measure, of the sulphate at 20 degrees, and agitating them together the mixture becomes turbid, after which a precipitation ensues, and the liquor grows clear. The quantity of the sulphate ought to be lessened or augmented according as the lixivium contains more or less of earthy nitrate. This is the method followed by M. Berard.

As soon as the lixivium is sufficiently sa-

turated, it is necessary to proceed to the process of evaporation.

This is performed in a copper caldron, or in lieu of it an iron one.

In proportion as the water is diminished by evaporation, its place is supplied by fresh lixivium. The evaporation is kept up during a few days until the liquor becomes sufficiently concentrated, as to yield crystals on cooling. When a portion of the liquor taken from the general mass readily crystallizes on being set in a cold place, it may be considered as a sufficient test of its concentration.

The waters when duly concentrated, are run off into crystallizing vessels of wood, earth, or copper; and after settling for a few days, the mother waters must be separated from the crystallized salt.

The mother waters are added to the lixivium, so that in a saltpetre work there may be always an equal quantity of each.

When the saltpetre is mixed with a great quantity of sea salt, which is uniformly formed with the nitrate, we avail ourselves of the property it possesses of being precipitated by ebullition, in order to separate it. This salt may

be removed by a ladle, when the evaporation is advanced, and put into an osier basket hung over the caldron to drain.

ARTICLE III.

On the Purification of Saltpetre.

The nitre obtained by a single crystallization is termed the *saltpetre of the first boiling*, or crude saltpetre. It cannot be employed in the composition of gun-powder, and other delicate operations, being very impure, and frequently containing muriate of soda, nitrates, and earthy muriates, a colouring principle, &c.

The art of purification consists in separating it from all those extraneous matters. The usual process adopted to attain this object is to dissolve 979,02000 kiligrammes (2160 lbs. 10 oz. 15 dr. avoirdupois) of coarse saltpetre in a copper caldron, in 793,21600 kilogrammes (1741 lbs. 6 oz. 3 dr. copper avoirdupois) of water.

In proportion as the solution advances by

the application of heat the saline film floating on the lixivium is taken away. They afterwards add to it 3,67128 hectogrammes of glue, (about 10 ounces) dissolved in ten pints of boiling water, and mixed with four buckets of cold water. This addition cools the lixivium, after which the liquor is agitated and the boiling quickly recommences. The film is carefully removed as before, and water added at different times, until no more scum arises.

The sea salt which crystallizes, is separated by means of a colander.

The liquor is then removed from the caldrons into large copper basins, to which is adapted a wooden cover to prevent the contact of the air. It is left to cool during four or five days. The salt thus crystallized is called by manufacturers the *saltpetre of the second boiling*.

This nitre is not yet sufficiently pure, as it still contains a portion of sea salt. A second refinement is therefore necessary in order to procure pure nitrate of potash.

After introducing 979,02000 kilogrammes (2160lbs. 10oz. 15dr. avoirdupois) of saltpetre,

of the *second boiling*, into a copper caldron, and adding the fourth of its weight of water, the fire is applied.

When the solution of the saltpetre is accomplished, the first scum is separated from it, a solution of 2,44742 hectogrammes, (about 7 ounces avoirdupois) of glue is added, and the liquor cooled by pouring into it one or two buckets of cold water. It is then briskly agitated in order to raise the scum, which is carefully taken off. When the liquor becomes clear and pure, it is emptied into copper basins, in which the saltpetre concretes into masses, which, at the termination of five days, are placed on a declivity on the ground in order to drain. Six or eight weeks are necessary to accomplish the desiccation. The nitre thus purified is termed *saltpetre of the third boiling*, and is used in the manufacture of gunpowder.

During the dreadful period of the revolution, when the French government saw itself attacked on all sides, it was found necessary to resort to scientific principles, in order to procure a supply of saltpetre, and gunpowder sufficient to equal the consumption. To ac-

complish this object, the usual methods of procuring saltpetre were abandoned, and new processes adopted in its preparation, which we shall here detail.

It was formerly known, that cold water possessed the power of dissolving muriate of soda, and of carrying with it deliquescent salts, and the colouring matter; we availed ourselves of this property, to deprive saltpetre, by repeated washings, of all the marine salt which it contains.

This method, which was proposed by Beaumé, has been perfected by M. Carny, and is thus conducted.

After breaking the crude saltpetre with mallets, it is introduced into coppers, and 20 per cent. of water added; the mixture is then stirred.

The solution is then left until no further augmentation takes place; six or seven hours are sufficient for this first operation, when the liquor is from 25 to 35 degrees of concentration.

This first water is poured off, and an additional ten per cent. of water is added to the same saltpetre.

The solution, after being stirred is left at

rest during one hour. The water is then drawn off.

They pour, for the last time, five per cent. of water upon the saltpetre, and set it to drain. The drained saltpetre is afterwards dissolved in a caldron containing fifty per cent. of boiling water. The solution indicates from 66 to 68 degrees of concentration.

This solution is afterwards put into leaden crystallizing vessels, about fifteen inches deep, and of considerable length. Crystals begin to be precipitated at the end of half an hour, and the whole process is finished in the space of from four to six hours.

But as it is of consequence to obtain the saltpetre in small needle-formed crystals, in order to facilitate its desiccation, the liquor is order to disturb the crystallization.

In proportion as the depositions form, we remove the salt to the sides of the vessel, and then put them, by means of a ladle, into the draining baskets.

This saltpetre is afterwards removed into wooden vats with double bottoms; the superior bottom is perforated with small holes, to carry off the water of the last washing, which

is performed with four or five per cent. of water.

This salt dries readily, and may be employed in the fabrication of gunpowder a few hours after. Its desiccation may be facilitated, when the weather is unfavourable, by means of a stove, or copper caldron in which it is heated.

This method of purification possesses the following advantages over that formerly practised.

It requires less fuel.

It is accomplished more expeditiously.

The saltpetre is desiccated more easily.

And the loss of salt is much less.

All these advantages have been demonstrated by a comparison of the two processes, in the first volume of my Elements of Chemistry.

ARTICLE IV.

On the Use of Saltpetre in the Composition of Gunpowder.

Gunpowder is formed by the accurate mixture of saltpetre, charcoal, and sulphur; and the different qualities of this powder depend

on the proportions between the constituent principles, the purity of the materials, and the accuracy with which they are triturated and mixed together.

The following are the results of the numerous experiments which I made in the celebrated powder manufacture at Grenelle.

1. The proportion of saltpetre ought to be at least about 75 per cent.

2. The proportions which produce the best gunpowder, are 77 saltpetre, 14 charcoal, and 9 sulphur.

The proportions most generally employed, are

76 saltpetre
12 charcoal
12 sulphur.

3. The proportion of sulphur may be diminished, or even omitted; but in this last case the powder is very porous, not sufficiently consistent, and is injured by carriage.

When the proportion of sulphur is diminished, it is necessary to triturate the other materials with greater care. I have obtained very good powder by employing 3 per cent. of sulphur.

The powder for ordnance requires less sulphur than the finer kinds.

Charcoal of white wood is employed in the making of powder, such as that of the poplar, willow, hazel, &c. It is made of the young branches of only two or three years growth.

The charcoal ought to be used immediately after being made, as it absorbs on exposure to the atmosphere, 20 or 25 per cent. of air and water, which injures its quality.

A very great difference is perceivable between the charcoal prepared in trenches and that prepared in the open air (vol. I. p. 114); the first is lighter, less compact, and is preferred for the composition of gun-powder.

All the powder manufactured in France is prepared by the trituration of the three materials, in mills furnished with an apparatus adapted to this purpose; and the mechanism of which is so well known as to render a particular description of it unnecessary. We shall at present, therefore, confine ourselves to give a succinct idea of the principal operations executed in the powder manufactures.

In the composition of the powder employed by miners, there is 13 pounds of saltpetre, 4 of sulphur, and 3 of charcoal.

In the fine powder used in war, 15 pounds of saltpetre, 2 pounds 8 ounces of sulphur, and 2 pounds 8 ounces of charcoal.

A single pestle is appropriated to each 20 pounds of the mixture.

The materials are first stirred with a stick, and a small portion of water added to them, in order to prevent the volatilization of the sulphur and charcoal.

The pounding usually continues twenty-one hours; the main velocity of the pestles is about 55 strokes in a minute; their weight is 80 pounds; and they rise and fall to the height of a foot.

It is removed from one mortar to another every hour, during the three first hours; and afterwards every three hours. At each change care is taken to preserve the necessary humidity, in order that the paste may retain its coherence. When the paste is sufficiently formed, the mixture perfect, and the division complete, it is taken out of the mortars, and deposited in the graining house.

As the paste retains a certain degree of humidity, it does not admit of granulation immediately on being brought from the mill; and

is therefore allowed to remain two or three days in the graining-house before this operation commences.

The granulation is performed by putting the dried matter into a sieve, of which the holes are in proportion to the size we wish to give to the grains. It is then covered with a piece of hard wood, from seven to eight inches in diameter by two in thickness, to which a rotatory motion is given, by moving the sieve upon a bar placed across a large vessel, into which the grains fall: that which is intended to be formed into minute grains, is usually prepared by first bruising it in a sieve, the holes of which are three lines in diameter.

They afterwards form the different kinds of grains, such as the *war-grain* for cannon, the *musket grain*, the *fine grain* for hunters, and the *superfine grain* for pistols, &c. by employing sieves, having holes of different diameters.

The powder which remains, after the separation of the grains, is moistened and again beaten for two or three hours.

When the granulation is finished, it is dried in the open air by spreading it on tables covered with linen cloths. It is turned ral

times a day, and allowed to remain in this situation until it be completely dry.

In the preparation of *hunters' powder*, the paste is only exposed to the air until it loses part of its humidity, and in this state 150 pounds of it is put into casks which revolve round their axis, and which are crossed by four bars parallel to the axis. The slow and continued motion thus communicated to them, produces a degree of friction which destroys the asperities of grains, and imparts to them a beautiful lustre.

After having polished this powder, it is exposed until perfectly dry.

It is then agitated in a sieve, in order to free it from any dust which may adhere to the surface of the grains.

This last operation is known among workmen under the name of *brushing*.

The same learned men commissioned by the government, who taught our manufacturers the prompt and economic method of purifying saltpetre, at the same time turned their attention to the improvement of those processes employed in the formation of gunpowder. The success of their labours was so great, that in

the space of few months 16 millions lbs. of saltpetre was produced in France; to such perfection indeed had they brought this art, that in the powder works at Grenelle alone, 34 thousand pounds were fabricated daily.

It is to M. Carny in particular that France owes the improved methods of making gunpowder; I have myself introduced some useful alterations in the different operations, but to M. Carny must be solely attributed the merit of the discovery.

We may reduce to three operations, every thing that is interesting in this new method of preparing gunpowder.

1. Pounding and sifting the materials.

2. Producing an accurate division and intimate mixture in the casks.

3. Giving to the mixture the requisite degree of consistence, and granulating the powder.

The pulverization or grinding of the materials, is performed separately by means of two bronze mill-stones running on the two extremities of the same axis, and turning in a trough.

The same machinery turns at the same time

four sieves, through which the pounded substance is passed in proportion as it is taken from the trough.

It is necessary that the sulphur should be finely pulverized. The same degree of accuracy is not required in respect to the charcoal and the saltpetre; they ought, however, to be carefully dried before being subjected to this operation.

When the different materials have been sufficiently pulverized, they are mixed together in the requisite proportions, and put into casks, or vats, 32 inches in length, by 22 in width.

These vats are solidly constructed of thick oak planks, and an opening made in one of their bottoms about 6 inches square, to which a cover is adapted in order to render it more convenient to put in and remove the materials. An iron axis covered with wood runs through the longitudinal diameter of these vessels; this axis, which projects at the two extremities, rests upon a wooden frame, and freely revolves upon itself; to the two extremities are adapted handles, in order to move the cask. Into each of these vessels are put 75 pounds of the com-

position; and they perform from 35 to 45 revolutions in a minute.

The mixture and trituration of the materials are greatly assisted, by introducing into every one of these vessels 80 pounds of bronze, in small balls, 4 lines in diameter; and by ledges, or mouldings, applied to the inner sides of the cask.

The composition is known to be sufficiently pulverized, when on a small portion of it being spread over a wooden pallet, with the blade of a knife, no roughness is perceptible; when the colour is uniform, and the knife experiences no resistance on its application to the pallet.

On the composition being taken out of the pulverizing vessels, the next operation is to give it the requisite degree of consistence, to fit it for granulation; and this is performed by strong compression, and the aid of a little water.

With this view, square pieces of walnut-tree wood are provided, 16 inches in length, by 1 foot in breadth, furnished with mouldings projecting from 5 to 6 lines. The inferior

edges of the platters are hollowed out, so as to correspond with the inner angles of these mouldings, in order that they may be readily placed within each other.

The operation is commenced by covering the bottom of one of the tables with a piece of moist linen; over this is spread a stratum of the composition, which is carefully covered with a similar piece of wet linen, and a second platter adapted to it, filled in the same manner as the first.

In this way, 23 platters are placed one above the other; the last of which is covered with a square piece of wood, and a heavy press screwed down upon the whole.

By this means a hard cake is formed, which is broken by the hand, and after being dried is subjected to the process of granulation. It was formerly my opinion, that this operation might be equally well performed, by means of a muller made to act on the composition. Experience has, however, convinced me, that this last process is in every respect preferable to the former.

This manner of forming gunpowder pos-

sesses numerous advantages; rapidity in the execution, economy in the consumption of the materials, superiority of the products, and safety in the operations.

In the first volume of my Elements of Chemistry, these truths are fully detailed and demonstrated.

CHAPTER XI.

On the Combinations of the Muriatic Acid.

The combinations of the muriatic acid have been long known by the uses to which they are daily applied; but the most common and useful of all these salts is that which this acid forms with soda.

The muriate of soda is found in immense masses in the bowels of the earth, or dissolved in the waters of the sea, or in saline springs; it generally accompanies the formation of saltpetre, so that though the muriatic acid is produced as it were under our eyes, yet to the present time we remain equally ignorant as to the mode of its formation, and the nature of its principles.

The muriates possess peculiar characters; they are not decomposable by heat, but are volatilized by it; they contain only a small quantity of the water of crystallization.

SECTION I.

On the Combinations of the Muriatic Acid with Soda.

The muriate of soda, which is also known under the names of *sea salt, culinary salt, &c.* has a penetrating and not unpleasant taste, and readily dissolves in the mouth.

It crystallizes in cubes, and each crystal appears to be composed of other small cubes inclosed within others.

Gmelin observed, that the salt of the brackish lakes, in the vicinity of Sellian, near the borders of the Caspian Sea, forms cubical and rhomboidal crystals.

Delisle informs us, that a solution of sea salt, which had been exposed during five years to the influence of insensible evaporation, near Rouelle, crystallized in regular octahedrons, like those of alum.

The muriate of soda may be obtained in octahedral crystals, by pouring recent urine into a solution of very pure sea salt.

Berniard affirms, that this addition changes

the form, without altering the nature of the salt.

This salt, when thrown on hot coals, decrepitates, and bursts into small pieces. It is afterwards deprived by the same means of the slight transparency which it possesses, and becomes opaque.

It resists for a long time the action of heat, even when pushed to redness; its grains slightly adhere to each other. Upon the application, however, of a more intense heat, it melts, and is volatilized.

This may be observed every day in glass-houses, when the salt which is mixed with the soda, fuses at the surface of the pots, and evaporates in a great measure during the refining the glass.

This salt, when in a pure state, does not effloresce; it attracts, on the contrary, moisture from the atmosphere, but not to such a degree as to become fluid.

It is soluble in two and a half waters, at 60 degrees of Fahrenheit. Water at 212 degrees dissolves scarcely a greater proportion; hence, when the water is saturated, it begins to precipitate immediately on the commencement of

evaporation, and is thus readily separated from all other salts which are dissolved with it in the same fluid.

Its specific gravity is to that of pure water in the proportion of 21,250 to 10,000.

According to Bergmann, its constituent principles are in the following proportions:

52 acid,
42 soda,
6 water.

According to Kirwan, when desiccated by a heat of 80 degrees of Fahrenheit, it contains

38,88 acid,
53,00 soda,
8,12 water.

The consumption of the muriate of soda is immense; it is also particularly known in society under the appellation of *salt*; an expression which though equally applicable to all the combinations of acids with different bases, is yet restricted by common use to muriate of soda.

The muriate of soda is used as a seasoning in many of our dishes; it tends to promote appetite and digestion, and is employed to preserve various animal substances intended to be long kept previous to their use.

Nature every where presents us with this salt in vast profusion. Not only do the waters of the sea furnish an inexhaustible store of this salt; but it is also found in immense masses under and above the earth's surface, as well as in many salt lakes and springs.

With the view of giving an exact idea of the manner in which this salt is procured, we shall consider it under the states in which it is found.

1. In solid masses beneath the earth's surface.
2. In solution in waters.

1. In the first state it forms what are termed *salt mines*. These mines are frequently found in mountains of a calcareous nature, as well as in the vicinity of a gypseous strata, and it is not unusual to discover in them shells, the impressions of fish, and other marks of

their submarine formation. The description of the salt mines in Siberia, Poland, Austria, and Transylvania, by Gmelin, Pallas, Macquart, &c. leaves no doubt on this subject.

Muriate of soda, when obtained from the mine, is of various colours; sometimes it is red, but seldom blue or green; hence it has received the denomination of *sal gemmi*.

The salt mines are wrought in the same manner as common quarries, and gun-powder is sometimes employed to facilitate the labour.

This salt is seldom found so pure as to render it fit for the common purposes to which it is applied. When this is the case it is purified by solution in water and crystallization.

Thus, according to Messrs. Jars and Duhamel, in the Tyrol, near Halle, they introduce fresh water into the works, made in the mine itself, in order to saturate it with the salt, after which it is conducted by means of wooden pipes into the evaporating vessels.

Nearly a similar method is practised in some parts of England, particularly in Norfolk and in Cheshire.

After digging the salt from the mine, it is

transported to Liverpool, where it is dissolved in sea-water, which, when fully saturated, is raised by means of pumps wrought by a wind-mill, and afterwards conveyed through pipes to be evaporated. They use the precaution of introducing whites of eggs previously beat up into a frothy mass with a little salt, and which they pour into the pipes communicating with the caldron.

They form in these salt works two sorts of salt, the one consisting of small grains obtained by a hasty boiling, the other composed of the grains produced by a slow and regular evaporation.

The mines of Wielicska in Poland, are by far the richest and most extensive of any yet known. Chapels and dwellings are excavated out of the solid rock of salt. The subterranean works are of such a prodigious magnitude that they extend upwards of three leagues. The workmen who are confined to labour in them, seldom live long; they generally die of complaints in the chest. They leave them every day, and work only about four hours at one time. The number, according to M. Berniard, amounts from 1200 to 2000. In 1785, when

Macquart visited these mines, they did not exceed 900.

Wood long preserves its texture in these mines, whereas bricks soon loosen and fall to decay.

The waters which filter through the works are conducted into a commodious reservoir, whence they are raised by means of large leathern buckets made of bullocks' hides, and poured into a rivulet which empties itself into the Vistula.

They have been so fortunate as to discover within the mine a spring of fresh water, which filters through an argillaceous sand bank from three to four feet in thickness. M. Born makes mention of seventeen fresh water lakes in the vicinity of these salt mines.

2. Exclusively of the mines of rock salt wrought in different parts of the earth, *common salt* is extracted from numerous saline springs, by the inhabitants of different countries remote from the sea.

It appears highly probable that these saline springs derive, for the most part, their origin from beds of salt; as they are usually found in

mountains bordering on them, or in hollows or caverns appearing to have contained originally salt in a state of solution. Similar observations have been made on the salt pits of Iletsky near Oremberg, and by M. Hassenfratz, on those of Mont Blanc.

Such saline springs may moreover derive their origin from lakes of salt water. Gmelin describes a lake of this nature, which supplies the springs at Tobolski and Jenissy, the waters of which are so loaded with salt, as to deposit a portion of it.

Saline springs abound in many parts of France, particularly in Lorraine, Franche-Comté, Savoy, &c. and as the art of evaporating the waters, for the purpose of extracting the salt, depends on a few general principles, to which the different operations may be referred, we shall at present confine ourselves to point them out.

The various establishments of this kind formed in Britain, for the purpose of separating salt from sea-water, appear to me to be conducted with equal economy and intelligence.

There is a work of this kind at Shields, a

sea-port about eight miles from Newcastle-upon-Tyne, in which they employ an immense number of caldrons for the evaporation of the sea water. These caldrons are made of thin iron plates, rivetted together by nails; they are from twenty to twenty-five feet long, by twelve to fifteen in width, and from two to three in depth. The water is taken at the height of the tide, and seldom indicates more than three degrees of concentration.

The caldrons are filled, and their contents evaporated till a pellicle forms on the surface of the liquor. They are then filled a second time, and the evaporation carried on as before. This process is repeated four times. At the fourth time, when the caldron is nearly full, they pour into the liquor a quart of bullock's blood, and carefully skim it, before the ebullition commences. Water is then added at five different times, and at the last, the use of the bullock's blood is renewed as formerly; after which they continue the evaporation nearly to dryness. The mother water is rejected as only containing muriates with earthy bases, or sulphates of soda and magnesia.

An incrustation of considerable thickness

never fails to be formed at the bottom of the caldron; this incrustation they remove once in two months, when it frequently equals nearly three inches in thickness. It appears to us to be principally composed of the sulphate of soda, deprived of the water of crystallization, such as it is observed in some salt pits in France.

In Scotland, in Cumberland, and other counties in England, the evaporation of sea-water is performed in nearly a similar manner; but in vessels of different dimensions. Thus, at Whitehaven, they are only 12 feet long by 12 in width; while at Kinnel they are 55 feet in length by 35 in breadth. There is also some difference in the method which they pursue of clarifying the liquor; in some of these places they employ whites of eggs, while in others they use bullocks' blood, &c.

In some countries they employ leaden caldrons for evaporating the water. In Hanover, and in the salt-pits of Luneburg, they are formed of a sheet of lead, the edges of which are turned up; their depth in the middle does not exceed three or four inches.

The caldrons employed in the Bearn, are nearly of a similar construction.

The methods pursued in some countries to concentrate the waters are extremely simple; the waters are pumped into vast reservoirs, and kept in perpetual agitation to facilitate their evaporation. In others they are conducted into a large reservoir, whence they are thrown in streams by means of cocks on thorns or spines heaped up to the depth of 18 feet. These waters are again brought back into the same reservoir, to be thrown off anew in the same manner, by which means there is produced a concentration equal to 11 or 12 degrees, after which the waters are transferred into the evaporating caldrons.

The relations of various travellers may alone convince us of the extreme industry exercised by man in different parts of the globe in order to extract the salt from sea water. In Japan, they dig holes which are filled with sand, into which the salt water is allowed to run, and afterwards left to evaporate. This process is repeated, till the sand be covered with saline incrustations. These are put into large tubs perforated with three holes in the bottom; into

these they throw more sea water, which is allowed to filter through the sand, after which it is evaporated.

The processes employed in the salt works at Avranches, in Normandy, nearly resemble those already described. They collect the sand impregnated with the salt of sea water during nine months of the year, and form it into heaps; these they cover with faggots, over which is laid fullers' earth, to prevent the water penetrating it; when the sand is to be lixiviated, it is washed in a ditch or trench, plastered with potter's earth, well incorporated, and lined with boards so placed as to allow the escape of the waters; these are evaporated in broad shallow vessels.

In Brittanny alone there are upwards of sixty small works of this kind.

In the South of France, particularly in Languedoc and Provence, they avail themselves of the sun's heat during summer, to evaporate sea water. With this view they fix upon a spot, into which the waters may readily flow, and which is not subject to inundations; they are likewise careful that the ground fixed upon for this purpose be firm, clayey, and impene-

trable to water, and that it be fully exposed to the action of the wind and the rays of the sun.

When a proper spot has been found it is divided into *compartments,* containing from 50 to 100 acres each.

These are surrounded by a wall, or strong bank, in such a manner that they are completely sheltered from the waves, and have no communication with the sea, either directly, or by filtration.

The large compartments are afterwards subdivided into smaller ones. This separation is effected by means of stakes driven into the ground, and by filling up the intervals by planks, fascines, and clay.

The sea water flows into the compartments, through passages which are opened and shut at pleasure. For this purpose, when the wind blows from the sea, and the water is propelled towards the coast, the passages are left open, but are shut as soon as a sufficiency of it has entered, in order to cut off all further communication with the sea.

The evaporation is performed by the influence of the sun, and by the perpetual agitation

in which the water is kept by the slightest motion of the air.

As soon as depositions begin to be formed, the water is pumped up on platforms plastered with clay; these platforms are subdivided into small compartments, and raised four feet above the former, in which the waters are prepared for subsequent operations.

The water is poured into each division to the depth of from 10 to 11 lines. The evaporation is finished in one day; after which more water is again poured in, and evaporated as before; and so on in like manner, successively for twenty days.

The stratum of salt thus formed is afterwards removed; it is generally about three or four inches in thickness.

It is scarcely necessary to observe, 1. That the surface of the ground plot of the divisions ought to be smooth and well levelled. 2. That the ground should be hard, and not admit of any infiltration. 3. That all the subdivisions ought to communicate with each other by a common trench or furrow. 4. That the table or platform is so much the better adapted to facilitate evaporation, as it is elevated above

the level of the waters. It is usually in the beginning of May that these operations are begun, in order that they may be terminated by the end of summer.

It is frequently found necessary to employ an iron instrument to detach the stratum of crystallized salt from the tables, particularly when it has been formed during the prevalence of a north wind.

At first the salt is built up in the form of pyramids upon the tables; these are taken down after twenty four hours, and collected into heaps of different dimensions. They cover the upper parts of these masses with straw or reeds. Each heap of salt is termed a *camelle.*

As soon as the first crop is collected, if the season be propitious, they proceed as before to prepare a second, which, however, never proves so productive as the first. Hence in Languedoc, they generally rest satisfied with the first quantity, and seldom attempt to procure a second.

The salt thus collected and formed into *camelles,* is purified and separated from the deliquescent salts, with which it is intermixed,

by its being left in the open air. These salts run off in copious streams, by means of furrows dug for the purpose.

In proportion to the age of the salt, these streams progressively decrease, and at last become dried up. The waters which thus run off, contain the muriates of lime and magnesia, and the sulphates of soda and magnesia. Some works are established in the vicinity of Narbonne for the express purpose of extracting these different salts, particularly the sulphates.

The keeping of the salt in heaps or *camelles*, for some months, operates to deprive it of that peculiar bitterness it possesses when recently made. Thus it is rendered hard, does not so readily deliquiate by the air, and becomes ready for sale.

The salt is meliorated according to the time during which it is kept in *camelles*. Formerly the salt manufactured at Pecais, was never exposed to sale till after a period of three years. At present, therefore, it is not held in the same estimation.

Since the suppression of the salt taxes, and

that the salt trade is laid open, the proprietors of such works dispose of their salt before it has undergone a sufficient degree of purification.

This practice excited some murmurs, but they have not been general; and it appears to me necessary to enlighten the public mind respecting the difference between recent salt, and that which has undergone depuration, and been well drained from the brine and bittern.

The recent salt is bitter and deliquescent, the reason of which has been already assigned; whereas that which has been kept for a length of time is of a penetrating taste, possesses solidity, and does not deliquesce on exposure to a moist atmosphere.

Hence it appears that recent salt is not well adapted for preserving meat, and similar purposes; it imparts to them not only a bad taste and vitiates their colour, but prevents them acquiring that firmness which is essential to their preservation.

Recent salt is moreover subject to great waste during its conveyance to any distance, as it relents in a moist air, and runs per deliquium.

But it appears to me that the recent salt is preferable to that which has been purified, when the object is to give it to sheep or cattle; for as the viscera of these ruminant animals are bulky and sluggish, they frequently become the seat of obstructions, the prevention or cure of which can only be obtained by confining them to the use of succulent and saponaceous herbage. Now as the earthy muriates are the most powerful solvents known, the recent salt which is impregnated with them, may be considered as a valuable prophylactic and curative remedy in many of the diseases to which cattle are liable; while old salt, on the contrary, seems best adapted for the preservation of meat and the uses of the table.

The crystals of this salt may be rendered perfectly transparent and colourless, and free from those matters which cause them to deliquesce, by solution in water and slow evaporation.

SECTION II.

Of the Combinations of Muriatic Acid with Ammonia.

The muriate of ammonia, which is known in commerce under the name of sal ammoniac, has the following characters:

1. It has an acrid, and extremely pungent taste.

2. It is of a grey colour, but convertible into a dull white by purification.

3. It is of a firm consistence, yielding and flattening under the hammer.

4. It is soluble in about three times and a half its weight of water, at 60 degrees of Fahrenheit, and an equal weight at 212 degrees.

During its solution in water, it produces a considerable degree of cold.

5. It smokes and evaporates when thrown upon live coals.

When sublimed in close vessels, it becomes

condensed into a hard compact mass, as if melted, particularly if the heat applied be intense.

By repeated sublimation it becomes white; and in this state is termed purified *sal ammoniac.*

6. Lime disengages from it the ammoniac in the state of gas, by the simple mixture of these two substances in powder.

Some metallic oxyds, as those of lead, produce the same effect.

The carbonates of lime, potash, and soda disengage it by distillation from the carbonate of ammonia.

7. It crystallizes in tetrahedrons, but most frequently in tetrahedral prisms, terminated by four-sided pyramids.

Frequently there are found in the concavity of sal ammoniac loaves, well defined cubical crystals; and sometimes even large tetrahedral pyramids, united at their base to longer pyramids, of which the aggregate constitutes the body of the loaves, as in spherical pyrites.

8. Its specific weight is, when compared with that of water as 14,530 to 10,000.

9. It consists according to Kirwan of

42,75 acid,
25,00 ammonia,
32,25 water.

Very little was known respecting the nature and preparation of sal ammoniac, till towards the beginning of the eighteenth century. Tournefort appears to have been the first who affirmed that this salt was composed of muriatic acid and ammonia.

In 1716, Geoffrey the younger read a memoir to the Academy of Sciences, with a view to prove that this salt was manufactured in Egypt, and that it was procured by sublimation. This memoir met with such opposition on the part of Homberg and Lemery, that it was never printed.

About three years after this period, M. Lemaire, consul at Grand Cairo, transmitted a letter to Paris, containing ample information respecting the mode pursued in the manufacturing of sal ammonia.

He informed us that it was prepared by sublimation from the soot which is produced by

burning the dung of cows and other animals, fed on marine plants.

Geoffrey published during the same year, 1720, a series of experiments, to prove that sal ammoniac might be manufactured in our laboratories.

Since that period, we have derived much additional information on this subject; and not only are we now acquainted with every circumstance relative to the preparation of this salt in Egypt, but have even learned the most economical processes of obtaining it.

We shall proceed to relate succinctly, all that we know respecting this important subject.

Hasselquist, the pupil of the celebrated Linnæus, has described, in a most circumstantial manner, the process employed in Egypt for preparing the sal ammoniac. It follows from the observations made by this able naturalist, which are inserted in the account of his travels in the Levant, that the chief substance employed in the preparation of this salt is, the soot produced by the combustion of the dung of animals, whose principal sustenance is

derived from marine plants, such as chenopodium, salicornia, &c.

The poor occupy themselves, during four months of the year, in collecting the dung of different animals; and when it is too soft mix it with cut straw to assist its desiccation; they place it against a wall that it may dry by the heat of the sun. This dried dung constitutes the only fuel used by the poorest class of the inhabitants. They carefully collect the soot produced by its combustion, and dispose of it to those who make a trade of preparing sal ammoniac.

The furnace in which the sublimation is performed, somewhat resembles an oven; in it are formed five ranges of cells, of ten inches each.

In each cell, or hollow, is placed a glass matrass, luted with mud from the Nile, and fitted with a neck, one inch in length by two in width. The matrasses are from ten to twelve inches in diameter.

They are filled with soot, while care at the same time is taken to leave a sufficient vacuity, in which the saline matter sublimed may settle.

The fire is kept up, for three days succes-

sively, by fresh supplies of dried dung. During this process, the heat is regulated with much care.

As soon as the matter becomes heated, there appears a blue, or violet coloured flame, which afterwards goes out.

When the sublimation commences, care is taken occasionally to introduce an iron wire, to prevent any obstruction forming in the neck of the matrass.

The distillation of 26 pounds of soot usually yields 6 pounds of sal ammoniac.

I have myself obtained sal ammoniac from the soot of cow-dung, and that of horses which run wild in the immense plains of Camargue, and Crau, and upon the borders of the numerous marshes in the vicinity of the Mediterranean; but it is necessary to mention, that sal ammoniac can only be procured from the dung of these animals, while they continue to live on marine plants.

Native sal ammoniac is found in various parts of the earth, particularly in the country of the Kalmucks, from which it is brought into Siberia, and sold for medicinal and other purposes. It is found ready sublimed, and adher-

ing to rocks, fragments of which it not unfrequently contains. It is also very often intermixed with sulphur. It is pulverulent and spongy.

Swab, Scheffer, Ferber, and other naturalists, have discovered sal ammoniac in the neighbourhood of volcanoes; it may be collected in the grottos of Pouzzoli.

It may be obtained by analysis, from various earthy matters, which have been produced by the decomposition of marine, vegetable, and animal substances; and it may be procured from some species of pit-coal, and from secondary schists by distillation.

Sal ammoniac is even formed in the human body itself, in consequence of a vitiation of its fluids. It is related in the Commercium Literarium Nurembergæ, for the year 1739, that a person, who laboured under an ardent fever, fell into a profuse perspiration of an ammoniacal nature, which put an end to the disease. Model relates, that when suffering under a febrile affection of a malignant kind, a profuse sweating supervened, which, in 4 days, removed the malady. As his hands were covered with a clammy sweat, he immersed them in a weak

solution of potash, upon which a strong ammoniacal odour became perceptible. He further informs us, that he often repeated this experiment, and with a similar result, in the naval hospitals.

Formerly we were wholly supplied with this salt from Egypt, but of late it has been furnished by European manufacturers in sufficient quantity to answer the consumption, and to supersede the necessity of foreign importation.

We shall now proceed to describe the processes employed in the formation of this salt.

In Belgium, the Duchy of Leige, and in some districts of Germany, sal ammoniac is prepared by burning a mixture of pit-coal, soot, argil, and sea salt.

With twenty-five parts, in bulk, of pulverized pit-coal, five of common soot, two of argil, kneaded into a paste, with a sufficient quantity of water, saturated with sea salt, oval bricks or loaves are formed 6 inches in length, about 3 inches broad, and 2 lines in thickness.

Fifteen to eighteen of these bricks, with bones interspersed between them, are burnt in a very small furnace, communicating by a little opening of two inches in diameter, placed

at the top of the door of the furnace, with an oblong vaulted chamber, about twelve feet in length by three in width. The soot, which passes through this chamber, escapes by another aperture formed at the opposite extremity, over against the first.

Several furnaces are disposed in the same line; and consequently an equal number of chambers ought to be constructed parallel to each.

All these chambers meet by the small opening formed over against the fire-place, in the opposite side, in a common gallery into which the exhalations pass, which have not been condensed in the first. At last, those vapours, which are purely gaseous, escape into the air by a chimney.

The combustion is supported, in these furnaces, during four, five, or six months. The soot, which adheres to the surface of the vault, and the sides of the chambers, is extremely light and saline, while that in the under part is greasy and poor.

The first depositions require only a single purification; but those on the floor of the

chambers, which contain a considerable portion of oil, require several.

The sublimation is performed in earthern retorts, about 18 inches in height, by 15 in diameter at the widest part. Into each retort, when heated, are introduced 7 kilogrammes, (equal to 15 lb. 7 oz. 3 dr. avoirdupois) of the materials.

They are placed in the cells, or hollows of a vaulted furnace, so that they may rest upon their belly.

The operation is finished in forty-eight hours.

Each retort yields 3 kilogrammes, (equal to 6 lb. 9 oz. 15 dr. avoirdupois) of sal ammoniac.

The depositions formed on the floor of the chambers ought to be again burned, or melted in the retort, and afterwards sublimed.

Each furnace furnishes 800 lb. of salt per annum.

This process, it appears to me, might be greatly improved.

For example, the animal substances should be mixed with the materials that enter into the composition of the bricks; and these materials should be kneaded with urine, or blood,

&c. It moreover appears to me, that the operation should be performed on a great scale, and that the substances mixed should be placed in a furnace of an orbicular form, that they should be kindled at the bottom, in order that the products disengaged may escape upwards, and be condensed in the chambers, at the moment when the heat having gradually pervaded the whole mass, elevates them into vapours.

Baumé had formed a manufacture of sal ammoniac, in which he procured ammonia by the distillation of animal substances. He decomposed afterwards, by this carbonate of ammonia, the muriates of magnesia contained in the mother waters of sea salt, and evaporated the water by which the muriate of ammonia was held in solution, after pouring it above the matter deposited; he sublimed the residuum of the evaporation, in order to separate the sal ammoniac from the other fixed salts that were dissolved in the liquor.

At Saint Denis, near Paris, Messrs. Leblanc and Dizé produced sal ammoniac by combining, in a leaden chamber, the vapours of ammonia and muriatic acid. The alkali was

supplied by the distillation of animal substances; and the acid by the decomposition of the muriate of soda by the sulphuric acid.

These two last processes are no longer followed; a more certain and economical method has since been adopted, and this we owe to Messrs. Pluvinet and Bourlier, who established the two first works of this kind in France.

They distil bones and woolen rags in large iron cylinders; the product is condensed in a succession of iron vessels, kept cool by the water in which they are immersed, and which open into a reservoir intended to receive the product of the distillation. This product is composed of animal oil, and the liquid carbonate of ammonia.

The supernatant oil is carefully separated.

The carbonate of ammonia is afterwards filtered through a stratum of calcined and pounded sulphate of lime. This stratum is placed on a linen cloth well stretched. Thus a decomposition is produced, from which results the sulphate of ammonia which passes through the filter, and the carbonate of lime which remains upon it. The filtration is renewed three

times, that the decomposition may be complete.

The sulphate of ammonia, treated with the muriate of soda by ebullition in a cauldron, yields muriate of ammonia, and sulphate of soda.

The sulphate of soda is separated by evaporation.

The residuum forms sal ammoniac by sublimation.

I am of opinion, that by throwing muriatic acid into privies, which exhale very strong ammoniacal vapours, we might produce sal ammoniac at very little expence. Some experiments which I have made on this subject, appear to me to warrant this opinion.

When we place shallow capsules, containing muriatic acid, in such places, a cloud of white vapours is produced, and in a very short time the acid becomes fixed, without however being neutralized.

I also endeavoured to transmit the vapours arising from the distillation of animal substances through the muriatic acid, and soon succeeded in saturating it. I have always

viewed this process as one of the most simple, and most economical.

Among animal substances, horns, bones, the chrysalides of silk worms are, in my opinion, the best adapted for this operation.

Sal ammoniac is known in commerce under the name of the *grey salt* and the *white salt*.

This last, however, differs only from the former in being more pure.

Each has its proper uses; the white is preferred for dyeing, while the grey is more employed for preparing iron and copper utensils for the operation of tinning. This preference was long considered as owing to the influence of caprice and custom; but an attentive examination has convinced me, that it is well founded.

When sal ammoniac is used in dying, it heightens the colour, and facilitates the solution of the tin, in forming the composition for the scarlet dye; and in all these cases it ought to be pure. Hence, therefore, the refined salt is justly preferred in such operations. But when sal ammoniac is employed in tinning, it is not merely necessary, that it should dissolve the oxidized metal, in order to clean its sur-

face, but it should also prevent all further oxydation; and the oil which exists in the grey salt, tends in an especial manner to produce this effect. Hence it is evident, that the choice of these salts must be determined by the use to which they are intended to be applied.

Besides the various uses which sal ammoniac serves in dyeing, and in tinning iron and copper vessels, it is also mixed at the present day in certain manufactures of tobacco, to give that article or the snuff made from it additional stimulant properties.

In pharmacy a great quantity of it is employed for the extraction of ammonia, or the volatile alkali.

SECTION III.

Of the Combinations of the Muriatic Acid with Tin.

The muriate of tin, better known under the name of salt of tin, has only been classed among the salts used in the arts, since it was employed as a mordant in the dyeing of cloth, and for brightening the colours of madder in dyeing cotton.

In order to prepare this salt, the tin is first divided, and after being digested with four parts of the acid in a sand bath ; the salt is afterwards obtained by evaporation.

But as the solution takes place slowly, and a portion of the acid is dissipated, I pass the acid vapours through a little water into a vase containing the tin which is to be dissolved and the solution is effected by the heat produced by the action of the acid upon the water.

The solution of the muriate of tin absorbs oxygen from the atmosphere, and even attracts it with avidity, from the greatest number of bodies with which it is combined. It may in some cases be even brought, according to the observations of Pelletier, into the state of an oxygenized muriate.

The solution of the muriate of tin, on long exposure to the air, changes to a brownish colour. During the evaporation of the solution of the salt of tin, such a penetrating odour is disengaged, as to prevent the chemist from remaining close to the evaporating vessels.

This salt is one of the heaviest with which we are acquainted.

It contains 19 of metal, 11 of acid, and 10 of water.

SECTION IV.

On the Combinations of the Muriatic Acid with Mercury.

The combinations of the muriatic acid with mercury, form two substances possessing very different qualities; the one is termed *sweet mercury*, the other is known under the name of *corrosive sublimate*. They appear to differ only in the degree of oxydation of the mercury, of which the oxyd in the corrosive sublimate contains 12,3 of oxygen to 69,7 of metal, while in that of *sweet mercury* it only contains 9,5 of oxygen to 79 of metal.

We shall describe these two combinations separately:

ARTICLE I.

Of Corrosive Sublimate.

The taste of this muriate, also known under the appellation of *muriate of quicksilver, cor-*

rosive muriated quicksilver, &c. is acrid, styptic, and durable.

It is semi-transparent, and of a white colour.

It is sublimed on exposure to the fire.

It is soluble in 20 parts of cold water, and in 2 at 212 according to Macquer.

This salt crystallizes by evaporation and by sublimation; in the first case it is sufficient to concentrate the solution, when it shoots into long flat acicular crystals. In the second case, when the sublimation is performed by a gentle heat we likewise obtain prismatic crystals in thin plates, of a brilliant white, fragile, and light.

This salt does not attract humidity from the atmosphere.

Lime water precipitates it in flakes of an orange-yellow colour, which gradually changes to a red brick.

Ammonia forms with it a white precipitate which quickly assumes a slate colour. According to Fourcroy, this is a triple salt formed by the oxyd of mercury, ammonia, and the acid in a state of the most intimate combination.

From Mr. Chevenix we learn that its constituent principles are in the following proportions:

Mercury 69,7
Oxygen 12,3
Acid 18

or in other terms:

82 oxide of mercury,
18 muriatic acid.

The corrosive sublimate has been hitherto chiefly prepared in Holland and England.

The processes successively employed with this view have attained different degrees of perfection. That, however, which appears preferable consists in mixing together by long continued trituration 280 lbs. of mercury, 400 lbs of sulphate of iron, calcined to redness, 200 lbs. of nitrate of potash, 200 lbs. of decrepitated muriate of soda, and 50 lbs. of the residuum of former operations, or when this cannot be procured, a like quantity of the residuum of aqua fortis prepared by vitriol. This mixture is divided into equal portions, each of which is put into a glass vessel of such dimensions that it is

only half filled by it; upon these vessels, which somewhat resemble cucurbits, are adapted heads, to which receivers are fitted. They are then sunk into a sandbath, to a level with the materials, and heat gradually communicated to them and kept up without interruption during five days. On the sublimation being finished, the receivers are raised up in order to take out the nitric acid they contain, and the vessels removed from the sandbath and set aside to cool. The product of each operation is about 360 lbs. of sublimate.

This process which was long practised at Venice, and afterwards at Amsterdam, has been so much simplified that they now only employ a mixture of equal parts of dry nitrate of mercury, decrepitated muriate of soda, and sulphate of iron calcined to whiteness.

In some places quicksilver is substituted instead of nitrate of mercury, while in others they supply, with greater propriety, the nitrate by the red oxyd of mercury.

Another method, published by Boulduc in 1730, has been long pretty generally followed; it consists in first forming a sulphate of mercury, by digesting in a cucurbit, three parts of

sulphuric acid, and one of mercury, in a sand-bath, exposed to a very strong heat; the white residuum which remains after the operation is then carefully mixed with equal parts of dry muriate of soda, after which the sublimation is commenced.

This method of Boulduc's has been greatly improved in Holland, where it is executed in the following manner.

They put into large stone cucurbits 50 lbs. of mercury and 25 of sulphuric acid, which is placed in a sand bath in the manner already mentioned, and the residuum is carefully mixed with 50 lbs. of muriate of soda, well dried and pounded.

The mixture becomes clammy, when it is distributed into pots arranged upon bars of iron in a furnace; each pot is covered with a lid, convex on the outside, and concave within, about the depth of from two to three inches, and perforated with a hole towards its middle, the joinings are then carefully luted, and the fire uniformly kept up till no more humid vapours issue through the hole in the lid; the fire is then augmented, and as soon as needles begin to form about the openings in the lids,

they are closed and covered with cold sand, and the bottoms of the vessels are kept of an obscure red heat, during thirty or thirty-six hours.

When the vessels are unluted a loaf of muriate of mercury is found on each lid.

If the mercury be precipitated from its solution in nitric acid by the oxygenated muriatic acid, corrosive sublimate is obtained.

It may also be formed by dissolving the red oxyd of mercury in common muriatic acid.

The qualities of the corrosive sublimate may be varied by dissolving the mercury at different degrees of oxydation, or by employing the sulphate of iron more or less calcined; or according to Scapoli by varying the proportions between the nitrate, the sulphate, the muriate, and the mercury.

ARTICLE II.

Of Sweet Mercury.

This salt, also known by the name of *calomel, submuriate of quicksilver,* &c. though formed

by the same metal, and the same acid as corrosive sublimate, yet possesses very different properties, and is distinguished by very different characters.

It is perfectly insipid.

It is insoluble in water and alcohol.

It crystallizes in tetrahedral prisms, terminated by four-faced pyramids, when sublimed by a gentle heat.

It fuses imperfectly by a strong heat which renders it semi-transparent.

The proportions of its constituent principles are according to Chenevix:

11,5 acid,
79,0 mercury,
9,5 oxygen.

or in other terms,

88,5 oxyd of mercury,
11,5 pure acid.

This salt is prepared in every laboratory; but is only manufactured on a great scale in Holland and England.

The usual method of preparing it is to triturate mercury with the corrosive sublimate,

and the proportions which appear to answer best, are four parts of corrosive sublimate, and three parts of mercury.

Sometimes equal parts are employed.

These two substances are carefully triturated until the mercury has wholly disappeared, and they form an uniform grey powder, which for still greater security may be levigated on a porphyry.

The subliming vessels are then half filled with this powder, and placed in a sand bath.

The fire is then gradually and progressively augmented, until a slight white vapour is observed to issue from the vessels; after which it is kept at the same degree from five to six hours.

The vessels, when cold, are found to contain in the upper part a very heavy, compact, saline mass, which is easily detached on breaking the vessels.

The convex portion of each loaf towards the summit, possesses neither the characters nor properties of sweet mercury: this portion it is necessary to separate from the other, in order that it may be triturated anew with mercury, and subjected to a second operation.

The sublimed muriate is pulverized and subjected to a second sublimation, the product of which is pounded and sublimed a third time; and it is this last product which is termed *sweet mercury*.

The preparation of the *mercurial panacea* differs from that of sweet mercury, by the latter being eight times subjected to sublimation.

By the trituration of mercury with corrosive sublimate a deleterious vapour is evolved, against which the operator ought to guard himself; to prevent this, Beaumé proposes to pour a little water on the mixture. Bailleau recommends to knead the sublimate with water, previous to its levigation with the mercury.

As the *sweet mercury* frequently retains some portion of corrosive sublimate, boiling water is poured on it, in order to purify it from this mixture.

It appears from the experiments of Beaumé, that repeated sublimations produce a small portion of corrosive sublimate, which seems to proceed from the progressive oxydation of the mercury by heat. Hence it follows, that the

panacea is a more doubtful remedy than calomel *sweet mercury.*

Beaumé has moreover proved, that there is no intermediate state between calomel and corrosive sublimate. If we add less mercury than the quantity of corrosive sublimate requires, there would only be produced a portion of calomel proportioned to the quantity of mercury employed; the remainder would still preserve all the characters of corrosive sublimate. If, on the contrary, we should add more mercury than the corrosive sublimate requires, in that case the superabundant mercury would be evaporated in a metallic state.

It is evident, that in the transition of the corrosive sublimate to the state of calomel, the oxygen of the former passes into the new metal in the proportion already pointed out.

If we digest, for a considerable time, the muriatic acid upon mercury, a solution of it takes place, and calomel is produced, as Homberg had observed at the beginning of the 18th century.

Calomel may also be formed by decomposing the nitrate of mercury by a solution of muriate

of soda. For this purpose, the muriate must be added in excess, that the decomposition may be complete. The muriate of the precipitated mercury must then be sublimed, in order to impart to it the appearance and characters of that sold in the shops.

CHAPTER XII.

Of the Combinations of the Oxygenated Muriatic Acid.

This acid forms particular combinations with several of its known bases.

Its combinations with the alkalis and earths, are decomposed by the contact of bodies in a state of conflagration, or by heat. In the first case a bright and speedy inflammation takes place; while in the second, there is a production of oxygen gas: in both cases, the salt passes into the state of a simple muriate.

When the oxygenated muriatic acid is presented to a metallic oxyd, it forms with it compounds which are almost all violent poisons, and very powerful escharotics, which in general attract humidity, rise in white vapours when exposed to the air, and have commonly a butyraceous consistency.

As at present the oxygenated muriate of

potash is alone applied to the purposes of the arts, we shall at present confine ourselves to its consideration.

SECTION I.

Of the Combinations of the Oxygenated Muriatic Acid with Potash.

In order to form the oxygenated muriate of potash, the oxygenated muriatic acid, which flies off in vapour, is made to pass through a strong solution of potash. In this operation there is formed a portion of the oxygenated muriate of potash, and of the ordinary muriate.

M. Berthollet has proved, by a series of well-contrived experiments, that the oxygenated muriatic acid which exists in the oxygenated muriate of potash, contained more oxygen than an equal weight of the oxygenated muriatic acid dissolved in water. This led him to consider the oxygenated acid combined in the muriate as hyper-oxygenized; and hence he inferred, that the ordinary muriatic acid may be regarded as a base susceptible of uniting

with more or less oxygen, and of forming in succession the oxygenated and hyper-oxygenated muriatic acid.

What furnishes a new proof of the truth of M. Berthollet's opinion, is, that when a solution of potash saturated with oxygenated acid is concentrated, we obtain a portion of ordinary muriate, and of hyper-oxygenated muriate.

As it is proper to purify the oxygenated salt from the simple muriate of potash, this object is attained by the facility with which the hyper-oxygenated muriate is precipitated by evaporation.

The solution of potash saturated with the acid is then filtered, and placed, for the purpose of evaporation, in a dark place, exposed to a gentle heat. In a short time, there is formed a deposit of brilliant and shining laminæ, like those of mica. This evaporation is kept up till the precipitate decrepitates, when thrown upon live coals, at the same time that almost the whole of it runs quickly into a state of fusion. The evaporation is then stopped, and it is left to cool; a portion of oxygenated

muriate is then precipitated, and the liquor is poured off to separate the deposit matter.

The oxygenated muriate crystallizes in hexahedral, and more frequently in rhomboidal plates.

It has an insipid taste, and produces, in the mouth a sensation of coolness, equal to that which is produced by nitre.

It fuses, when thrown on burning coals, with more facility and intensity than nitrate of potash.

One hundred grains of this salt yield 75 cubic inches of very pure oxygen gas.

It is easily decomposed when exposed to the air, and passes into the state of ordinary muriate.

A solution of this salt may be employed to bleach flax, hemp, and cotton threads; but the quantity of oxygenated muriatic acid which enters into the salt employed, will produce more effect when used alone, and free from combination.

M. Berthollet has substituted this in place of the nitrate of potash, in the fabrication of gunpowder; and has obtained a product infinitely more terrible in its effects, than the

best gunpowder that has been hitherto fabricated with the nitrate.

The gunpowder, on which the chief experiments have been made, was composed of six parts of oxygenated muriate, one part of sulphur, and one of charcoal.

A mixture of these substances is moistened in such a way as to form a paste, which is carefully brayed upon marble with a mullar of hard wood. This precaution is necessary to guard against the accidents which might happen from the explosion of a substance so dangerous. It would be imprudent to produce this mixture by the employment of common mortars; and the unfortunate experiment at Essonnes had consequences too destructive, that we should again attempt to renew it.

The comparative trials, made in the Arsenal at Paris, April 27, 1793, between muriated gunpowder, and superfine gunpowder of nitrate, gave the following results.

1. By the powder-proof of Darcy, consisting of a cannon which, suspended at the extremity of a bar of iron, described by its recoil an arch, of which the degrees were measured:

	Recoil.
2 drams of muriated gunpowder	$15\frac{2}{20}$
2 —— of the same wetted	$14\frac{1}{20}$
2 —— of nitrated gunpowder	$10\frac{7}{20}$
2 —— of the same -	$10\frac{1}{20}$
3 —— of muriated gunpowder	$20\frac{3}{20}$
3 —— of nitrated gunpowder	$16\frac{6}{20}$.

Whence it follows, that in this trial, the muriated gunpowder shewed a superiority of force to the amount of nearly one-fourth.

2. By the powder-proof of Regnier, consisting of a spring which closes the mouth of the cannon, and which is driven back by the explosion, to a distance more or less great, measured by the degrees of an arch which it runs through :

Muriated gunpowder -	42
The same - -	$51\frac{3}{4}$
Muriated gunpowed moistened	52
Superfine nitrated gunpowder	23
The same - -	$22\frac{1}{2}$

From this trial it results, that the force of

gunpowder of muriate is double that of nitrate. But as this gunpowder explodes with such facility, that the jolts of carriage, nay, even the least shock may produce disagreeable accidents, it is prudent to reserve the use of it for delicate and extraordinary operations.

CHAPTER XIII.

Of the Combinations of the Tartareous Acid.

SECTION I.

Of the Combinations of the Tartareous Acid with Potash.

This salt, otherwise termed *acidulous tartrite of potash, cream of tartar,* &c. is ready formed in wine, and adheres to the sides of the casks containing that liquor.

It is well known, that on the termination of the various fermentation, and when the wine settles in the casks, a ropy matter is precipitated, forming a muddy deposition at the bottom of the liquor, while a more saline substance adheres to the sides of the vessels, covering them with a crust of greater or less thickness, which is readily taken off with a sharp instrument, at the time the cask is to be

prepared for receiving the product of a new vintage. This matter is given to those who clear the casks, and serves instead of wages, at least in the south of France; they collect it with care, and sell it to dyers, founders, and particularly to the manufacturers of cream of tartar.

The price of this substance varies according to the nature of the wines: there are districts, such as those on the banks of the Rhone, the wines of which yield a heavy granulated tartar, and containing only a small portion of the extractive principle, and consequently in great request for the manufacture of cream of tartar; while there are others, which furnish a tartar neither thick nor hard, rich in the extractive principle, difficult to purify, and of little use in those operations in which the salt only produces its effect, in proportion to the saline principle which it contains.

All wines do not furnish tartar of the same quality; they do not all yield even the same quantity: strong and generous wines contain more than others; wines that are weak and light yield almost none at all.

The reddish colour of tartar is always in

proportion to the strength of that colour in the wine which furnishes it. It is those shades of colour which have given it the name of *white*, or *red tartar*, according as it is obtained from white wine or red

I have often had occasion to observe that the tartar shoots into crystals, sufficiently marked to admit of description; they are usually in the form of short tetrahedral prisms, cut slantingly at the two extremities.

The crude tartar when taken from the casks is very little employed in the arts; in this state it only serves as a flux in some metallurgic operations. In order to fit it for the purposes of commerce it is deprived of its colouring principle, and also of a portion of its extractive principle; when we give to it the name of *cream of tartar*.

From time immemorial, they have been in possession, at Montpelier and its neighbourhood, of the mode of purifying tartar; the process has been described by Fizes, and inserted in the Memoires of the Academy of Paris, for the year 1725. It is so simple, and the result is so profitable, that almost no change

in the operation has taken place since that period.

With the best granulated tartar, properly divided, they saturate the water contained in a copper carried to the boiling point. The solution is then allowed to cool and carefully poured off from the deposition which has taken place, into wide pans. To the sides of these pans, a pretty thick layer of crystals of tartar adheres, which are disengaged from a considerable portion of their colouring principle.

They dissolve these crystals in boiling water, in which they mix from 4 to 6 parts of clayey earth to 100 parts of salt. Evaporation goes on till a strong pellicle is formed on the surface; it is then left to cool, when they obtain crystals, which are exposed for some days to the heat of the sun upon linen cloths, in order to dry, and to acquire the utmost degree of whiteness.

The *cream of tartar* prepared by this process is always very white, and in beautiful crystals. But as it is of importance to derive all the advantage possible from the *mother wa-*

ters, which retain a part of the colouring principle, it is usual to pour off with care the solution which swims above the crystals, and to return it into the coppers where these last were dissolved. They employ only, however, that which is limpid, and pour the muddy liquor into appropriate vessels, for the purpose of depuration. By decantation and filtration they succeed in depriving it almost wholly of its colouring and extractive principle. To convert to profit all these residuums, they may be employed in small quantities in each operation; or they may be treated separately and with care, in order to extract every particle of cream of tartar.

This process is founded on three incontestible principles; the first is, that the tartar is more easily soluble in boiling than in cold water; the second, that clays have the property of seizing upon the colouring, extractive, and ligneous principles, and of purifying vegetable and saline solutions; the third, that exposure to the air destroys the colouring principle of vegetables, and ought, therefore, to produce the utmost degree of whiteness in the cream of tarrar.

The earth which is used, is brought from Murviel, three miles from Montpelier. It is a sandy clay, sufficiently white, arising from the decomposition of hard stone, and of the colour of *silex;* this earth is friable, but it is less easily diluted in water than the pure clays, and is more readily precipitated.

I have substituted, with much advantage, the fine argil of Cornillon, in the department of Gard, instead of that of Murviel. Besides being whiter, it is more divisible in water; it unites itself when dissolved, more completely with the matters suspended in its solution; in short, repeated experiments have convinced me, that it might successfully supplant the earth of Murviel; though the difference of price, occasioned by distance, has hitherto prevented its employment. It may be observed, however, that as the clay of Cornillon is found almost in the centre of those districts which furnish the best tartar, it would be advantageous to establish in the vicinity refining manufactories.

We ought not to employ a marley earth, nor the fuller's earth used in our southern provinces for fulling cloth, as they all contain a portion

of chalk, which, saturating the acidof the cream of tartar and imparting to it a foreign principle, necessarily injures its quality. And even though the chalk should only remain interposed between its crystals, this simple mixture would render it improper for dyeing, since lime is destructive of almost all colours.

M. Desmaratz has described, in the Journal de Physique for 1771, the process employed at Venice for purifying tartar. They dry the tartar in its crude state, and the lees of wine, in iron pots, by a moderate heat; they then pulverise the residuum, and distribute it in tubs filled with warm water, where the solution is promoted by agitation. By cooling alone, the impurities are precipitated to the bottom, and the crystals of tartar adhere to the sides of the vessels. These are again dissolved in water, and made to boil in a large copper, where they are clarified with the whites of eggs. A few recent ashes are at the same time thrown into the copper, which produce a considerable effervescence, and bring to the top much scum, which is immediately taken off. This operation, repeated four or five times, leaves at

last a colourless liquor, which deposits very white crystals by continued evaporation.

According to the process followed at Venice there is introduced into the solution of the tartar, a foreign substance which must saturate a part of the acid, a circumstance which in most cases, must modify the properties which belong to cream of tartar in a pure state. It is therefore obvious that the process employed at Montpelier is preferable.

The cream of tartar assumes very generally the form of four-sided prisms, of which the extremities are cut in a slanting direction. The crystals are almost always in groups; and they frequently diverge as from a common centre.

Cream of tartar, in order to be pure should be white.

It has an acrid harsh taste.

It dissolves slowly in the mouth, and feels gritty under the teeth.

It fumes upon coals, diffuses an empyreumatic odour, and leaves a carbonaceous residuum, which becomes white by incineration

An ounce of water at the temperature of 10+0 (Reaumur) dissolves only 4 grains of tartar; while according to Wenzel, 30 parts of boiling water dissolve one of cream of tartar.

According to Spielman, one ounce of cold water only holds in solution 3 grains.

As cream of tartar produces no effect on the human body, but when taken in such a dose that the quantity of water necessary to dissolve it would form too copious a draught, the means of rendering it more soluble have been long a desideratum, and the following have been employed with this view. Lemery had observed that 2 ounces of borax mixed with 4 ounces of cream of tartar in powder, and boiled during a quarter of an hour in 12 ounces of water, dissolved quickly, and did not crystallize on cooling. (See the Memoirs of the Academy of Paris for 1728.)

At present this method has been proposed as a discovery, and has been pompously announced to the public.

It is a fact that the solution of the mixture is effected by adding to it a fifth part of borax. But is not the cream of tartar thereby

changed? Is its medicinal effect the same? While in expectation that the observations of intelligent physicians should enlighten us on this subject, chemistry has resolved the question. As the tartareous acid has a greater affinity for the alkalies than the boracic acid, not only must the acid of the cream of tartar saturate the soda, which is superabundant in the borax, but deprive it of its base. Hence, therefore, a triple salt will be formed, or a tartrite of soda and potash, which is extremely soluble in water; and the boracic acid being disengaged from a portion of its alkaline base, must remain mixed in the liquor. Thus then we obtain a solution of tartrite of soda and potash, *Rochelle salt,* acidulated with the boracic acid.

M. Lassone proposes, in the Memoirs of the Academy of Sciences, to dissolve four grains of cream of tartar in four ounces of water, and to add one grain of boracic acid. This addition possesses the double advantage of preventing the precipitation without decomposing the cream of tartar.

Sugar has also been proposed in order to fa-

cilitate the solution; but it appears to act only by thickening the liquor, and preventing the precipitation of the insoluble matter; the British compose in this way a purgative lemonade, which excites no nausea.

Cream of tartar consists merely of potash, with an excess of tartareous acid.

The potash may be separated by the mineral acids, combustion, distillation, and even by the spontaneous decomposition of a solution of tartars, as Messrs. Mackie, Corvinus, and Berthollet, have observed. In this last case there are formed flakes or pellicles in the liquor, which continually augment till nothing is left behind but an alkaline liquor.

This decomposition occurs equally in close as in open vessels, according to the observation of M. Berthollet. All the results of the extraction of potash from its acid concur to prove, that the latter is contained in it nearly in the proportion of three-eighths.

Cream of tartar is much employed in dyeing, in which it is usually combined with alum.

In this case, its acid enters into union

with the alumine, and is precipitated on the stuff.

It serves besides, in the north, the same purposes for which we employ the common salt at our tables; and forms in this respect a very great article of consumption.

CHAPTER XIV.

On the Combinations of the Acetic Acid.

The acetic acid which is procured from wine or beer, and by the distillation of wood, and other parts of vegetables, is of all the acids that which is most generally known, and the most frequently employed. Not only is it used at our tables to correct the insipidity of various kinds of food, and as a seasoning for many others; but is also employed in the manufacture of ceruse, sugar of lead, verdigrise, &c.

The metallic salts formed by this acid possess this peculiar advantage, that when employed in painting and dyeing, the acid contained in them does not corrode the substances to which it is applied. It may be diluted in a dyer's vat without inconvenience, an advantage which is not possessed by any of the other metallic salts.

ARTICLE I.

Of the Combinations of the Acetic Acid with Lead.

This combination, termed by chemists the *acetate of lead*, is known in commerce under the various appellations of *salt of lead, sugar of lead*, &c.

France, Holland, and England, supply all the salt of lead which is used in the arts. In France it is prepared with vinegar obtained from wine, while in Holland and in England they employ that produced from beer.

This salt is of a sweetish taste, on which account it has received the name of *sugar of lead.*

It is decomposable by heat, and leaves a yellow residuum.

It decomposes the sulphates of lime, of alumine and of magnesia, as well as the muriates. From the decomposition of the sulphate of alumine by this salt, there is formed an acetate

of alumine, which constitutes the principal mordant in printing cotton cloth.

This salt when exposed to the action of sulphuretted hydrogen gas, assumes a blackish tint.

Its solution in water constitutes what is termed the *aqua Saturni*, the *vegeto-mineral water* of Goulard.

The specific weight of the acetate of lead is 2,345.

It crystallizes in flat tetrahedral prisms, terminated by dihedral summits.

In those provinces of France where wine is the principal product, and where of course the quantity of vinegar produced far exceeds what is required for domestic use, it has been applied to various purposes. Thus in the principal cities of Provence, such as Toulon, Draguignan, Marseilles, Aix, extensive works have been established for the preparation of sugar of lead; and though the processes followed be far from perfect, yet the salt is furnished at such a low price, that they have hitherto operated to prevent the formation of similar establishments in other parts, particularly in the north of France.

The process followed in Provence consists in oxydizing plates of lead by the vapour of vinegar, in dissolving the oxyd in the acid, and evaporating it in order to obtain the salt in crystals. For this purpose they form the lead into very thin plates, and the vinegar is subjected to distillation.

Earthen capsules or dishes are disposed on stages round the workhouse; into these capsules are introduced 4 or 6 pounds of lead, on which is poured 1 pound of distilled vinegar. Thus there is formed on the surface of the metal, not immersed in the vinegar, a white oxyd which is scraped off, and thrown into the acid for the purpose of solution. The manufacturers, however, usually content themselves with turning over the plates, that the oxydized surface may be covered by the acid, while that which has not undergone oxydation, may be exposed to its vapours. These operations are alternately repeated twice or thrice every day.

Care is taken to add new plates, in proportion as the former are wasted, so that the capsules may be constantly filled by them.

The acid assumes, by degrees, a grey whitish

colour, and when sufficiently saturated, is transferred into tinned cauldrons, to which heat is applied, in order to perfect the combination.

When the bulk of the liquor is reduced to two-thirds, it is filtered, and evaporated till crystals begin to shoot; after which it is removed into the crystallizing pans. As soon as the crystallization is completed, the vessels are inclined in order to favour the efflux of the mother water from the middle of the crystals. The salt is thus rendered white, and when dry, they divide the loaves into parts for the purpose of sale. Each part, or fragment, is composed of an aggregation of small acicular crystals; these however, are separate and detached, when the salt has not been suitably concentrated.

M. Pontier has communicated some interesting observations on this operation; an account of which has been published by M. Vauquelin, in the Annales de Chimie, vol. 37.

The salt of lead may be procured by dissolving the white oxyd of lead in the acetic acid; but for this purpose it is usual to employ litharge previously well sifted, in order to free it from the impurities, and any frag-

ments of vitreous oxyd which it may contain.

With this view the acetic acid is saturated, with litharge added to it by degrees, while at the same time the liquor must be gently agitated to prevent the deposition of the oxyd. One part of litharge is necessary to saturate ten or twelve parts of vinegar, at the fourth or fifth degree of concentration.

As soon as the solution is finished, the liquor is left to settle, in order to assist the clarification. It is then poured off and evaporated in another cauldron.

The solution of the oxyd may be readily effected in cold water, so as to mark 25 degrees of concentration. This method is the most economical.

The evaporation is performed in copper cauldrons. Those of lead are acted on, and dissolved in a short time by the boiling acid. The copper cauldrons would quickly be affected by the action of the acid, were it not obviated by the introduction of ingots of lead into the cauldron, on which the acid seizes in preference to the copper; these ingots must be

replaced by others, in proportion as they are wasted.

When the liquor marks 70 degrees of concentration, a small portion of it may be set aside in a glass capsule to cool, to enable us to judge whether the evaporation has been carried to a sufficient length.

When the liquor has been evaporated to a certain point, it is transferred into earthern vessels to crystallize. It runs together into a mass; and after leaving it at rest for two days, the vessels are placed in a slanting position to favour the efflux of the mother water from the crystals. This may be still further facilitated by making openings in the mass with a knife.

In proportion as the crystals are deprived of the black mother water, they assume a white colour, and present a dry mass, or aggregation of glossy crystals of a greyish white.

This salt differs, in appearance, from that which is prepared in Holland. This last salt forms heavy compact masses, composed of large irregular crystals.

It not unfrequently happens, that the concentrated solution will not crystallize; but

degenerates into a *magma*, or jelly. This circumstance, for the most part, proceeds from the oxyd being superabundant, and may be remedied by adding to the liquor a fresh portion of vinegar. The acid from beer dissolves the oxyd of lead without the aid of heat, and the solution may be concentrated to twenty-five degrees, but the filtrated liquor becomes turbid by rest. Its evaporation produces unseemly small crystals, mixed with a white *magma*. By dissolving the whole in more acid, and concentrating it by evaporation, the acetate may be obtained in most beautiful white crystals. This is at least conformable to my own experience.

Instead of the oxyd the metal itself may be employed. To this purpose it is reduced into small grains, by pouring it into water, and making them fall together from a height of several feet. A stratum of these grains is then formed in a cask, on which vinegar is repeatedly poured, and withdrawn by an aperture formed in the bottom. The lead thus moistened becomes heated and is oxydized. The oxyd is dissolved by repassing the vinegar

through the stratum. This solution ought to be concentrated to 10 degrees, by two or three successive operations.

If the concentration be carried further, crystallization does not take place; but this may be corrected by again reducing the liquor to 10 degrees by the addition of more acid.

In all cases in which there is exhaled, during ebullition, a very penetrating odour of vinegar, we may conclude that more of it is required. It seems in this case, that the acetate suffers decomposition, and yields up its acid.

Much depends on the choice of the vinegar in the preparation of this salt. In general, the strongest distilled vinegar is employed for this purpose. When we purchase indiscriminately all kinds of vinegar, as they are found in the market, and employ them in this state, we experience great variations in the qualities of the product, as well as difficulties in the operation, which frequently disconcert the manufacturer, because, seldom possessing much scientific knowledge, he knows not how to remedy them. These vinegars are very often wines slightly *soured*, or as the people judiciously

term them, wines beginning *to catch air*. These vinegars yield also by distillation a small portion of a spirit, very disagreeable to the taste. This quality is in my opinion attributable to a considerable quantity of malic acid, from which it is very difficult to free it.

In manufactures of salt of lead, conducted on a great scale, it is necessary to employ those large vats, vernacularly termed *foudres*. Into them the vinegar is poured, and left to acidify for a considerable time. As soon as one of the vessels is emptied, another is filled, by which means an acid of equal quality, and of the best kind, is obtained.

It must be observed, that vinegars which are not properly prepared, when combined with the oxyd of lead, do not crystallize by evaporation. This inconvenience may be remedied, by mixing with the solution one-hundredth part of nitric acid; but this addition is unnecessary, when vinegar of a good quality is employed.

SECTION II.

Of the Combinations of the Acetic Acid with Copper.

Acetate of copper, crystals of Venus, and *verdigrise,* are synonymous terms, expressing the combination of the acetic acid with copper.

The acetate of copper is one of the prepatations of copper which is very much used in the arts. Not only is it employed by painters, but also by dyers, on many occasions, with the happiest offects.

Mostly all the oxyds of copper, obtained by the action of saline substances on this metal, possess a blue colour, inclining more or less to green.

All the neutral salts, nearly without exception, corrode this metal, and produce that oxydation, which is denominated *verdigrise.* For this purpose, it is sufficient to bring them into contact with the metal, or to soak the metal itself, in the form of plates in the saline solution, and on withdrawing them, to expose

them to the action of the air, and to leave them to dry.

The acids which oxydize the copper, by their action on it, produce an effect similar to that of the neutral salts. The oxyd is of a delicate and bluish green colour. The action of some of the acids is so rapid, that it suffices to expose the metal to their vapours, only for a very few minutes, to oxydize its surface. The oxy-muriatic acid produces this effect, as well as the vapours of the nitric, and those of the sulphuric acid.

A phenomenon which cannot escape an attentive observer, is, that the oxyds of copper, obtained by heat, are very different from those produced by the action of the acids on the same metal. Their colour is grey, instead of green; and when we push the calcination, by an intense and long-continued heat, they may be reduced into the state of a red oxyd of the colour of blood.

This phenomenon did not escape the notice of Kunckel.

The power of converting copper into a green oxyd is not exclusively confined to saline substances. All oleaginous, and fatty matters,

produce the same effect ; water itself, when left for some time in copper vessels, never fails to oxydize them.

But what may appear very extraordinary is, that the greatest number of these substances act only on the copper at a low temperature.

The salts themselves, which corrode this metal, when left in contact with it, never attack it in such a marked manner as when agitated by ebullition.

Of all the preparations of copper by oxydation, none is more valuable than that which is produced by the acetic acid. All the verdigrise of commerce is prepared by means of this acid ; and it is particularly at Montpelier, and in its vicinity, that the most extensive manufactures of it are established.

There may be seen, in the Memoirs of the Academy of Paris, for 1750, and 1753, a very accurate account of the process which was then followed, in the manufacture of verdigrise, at Montpelier ; but as this process has been since greatly improved, and as, instead of employing grape stalks and wine, they confine themselves to the refuse of the grape, which is found to be much more economical : we think

it necessary to detail the process now employed for obtaining it.

The substances most essential to the preparation of verdigrise, are copper, and the refuse of grapes.

The copper formerly employed in France for this purpose, was imported from Sweden; but at present it is procured from the different foundries established at Saint-Bel, Lyons, Avignon, Bedarieux, Montpelier, &c. It is manufactured in round sheets, from twenty to twenty-five inches in diameter, by half a line in thickness. Each sheet is divided, at Montpelier, into 25 plates, forming oblong squares, from 4 to 6 inches in length, by 3 in breadth, and weighing about 4 ounces. They are separately beaten upon an anvil, to unite their surfaces, in order to give to the copper the requisite degree of consistence.

Unless this precaution be employed it exfoliates, and much difficulty is experienced in scraping the oxyd from its surface. In this way likewise scales of copper are raised up, which occasions a considerable waste of metal.

The refuse of the grapes, after the extraction of their juice, known at Montpelier un-

der the name of *raque*, was formerly thrown to the dunghill, after the small grains contained in it had been devoured by poultry; at present it is preserved for the purpose of making verdigrise, and is sold at from 15 to 20 francs, equal to 1 *l.* sterling the hogshead, and is prepared as follows:

As soon as the fermentation of the grapes has ceased, they are subjected to the press, in order to express the wine which they contain; the expressed substance is then put into casks, and carefully trodden down by the feet, in order to render the mass as compact as possible; the casks are afterwards carefully covered and set aside in a dry situation until wanted.

This substance is not always of the same quality; when the grapes are not saccharine, when the season has proved rainy, or when any accident has rendered the fermentation incomplete, or even when the wine is not of a strong body, it is found defective in several respects:

1. It is preserved with great difficulty, being apt to corrupt in a short time after it is put into the casks.

2. It produces little effect, heats with diffi-

culty, evolves little acetous odour, and causes the plates of copper to *sweat*, without producing the green downy matter termed verdigrise.

Independently, however, of the nature of the grape, and the state of the wine, the quality of the refuse varies according to the care with which it has been expressed. That which has been rendered perfectly dry, produces less powerful effects than that in which part of the juice remains.

In order to explain the different effect produced by this substance, it is sufficient to observe, that it acts merely from the quantity of wine contained in it, since it is only this liquor which can pass into a state of vinegar. Thus then the refuse intended, for the use of verdigrise makers, should be subjected to a less degree of pressure than usual, in order that it may retain more of the principle of acetification.

After providing a sufficient quantity of this refuse, and of copper, the subsequent steps are conducted as follows:—The different operations are usually carried on in cellars, though

they would succeed equally well in apartments on a level with the ground, provided they were sufficiently damp, of an uniform temperature, and did not admit too much light.

The first part of the process consists in fermenting the expressed grapes; for this purpose they break up one of the casks, and distribute the materials into two others of equal dimensions, taking care to compress them as little as possible. The contents of one cask ought to fill two, and occupy at least a double space after this operation.

In some works of this kind, they divide the refuse contained in one cask, into twenty or twenty-five earthen vessels, which are usually 16 inches in height, by 14 in diameter at the widest part, and about 12 at the mouth. The vessels are then slightly closed with lids, which are not however fixed down. The openings are surrounded with straw wrought for the purpose.

In this situation the materials soon become heated, which may be observed by plunging the hand into one of the vessels, and by the acid odour which begins to exhale from them.

The fermentation commences at the bottom of the cask, and gradually ascending, at length pervades the whole mass. During this process, Reaumur's thermometer ascends to 30 and 35 degrees, at the end of three or four days the heat diminishes and disappears; and as the manufacturer is afraid of losing a portion of vinegar which is the natural consequence of long continued heat, he takes care after the fermentation has continued three days to remove the fermenting materials from the vats in order that they may cool more rapidly. Those who employ casks transfer them into stone vessels, and those who use the stone vessels as fermenting vats, remove them into others of the same kind. Besides the loss of acetous spirit, long continued heat imparts a mouldiness to the residuum, or *raque*, which renders it unfit for the production of verdigrise. In order to augment the effect of the expressed grapes, they are formed into a heap and sprinkled with strong wine previous to fermentation.

Fermentation does not always take place in the same time, nor proceed with the same activity. Sometimes it appears in twenty-four

hours, and at others it does not commence till after the termination of three weeks.

The heat is sometimes so considerable, that it is impossible to retain the hand in the mass, and at the same time a strong acetous odour is diffused round the fermenting vessels; while at others the heat is scarcely perceptible, and very quickly disappears. Cases even occur in which the materials putrefy, become mouldy, and remain perfectly vapid. The fermentation is encouraged by increasing the heat of the apartments by means of stoves, covering up the vats with blankets, shutting the windows, and stirring up the materials in order to give them air. The differences in the fermentation depend, 1st. on the temperature of the atmosphere; thus fermentation is more rapid during summer; 2d. on the nature of the fermentable materials; that which is produced by sweet grapes heats most easily; 3d. on their quantity; a large mass of materials ferments more quickly, and with greater activity than a smaller quantity; 4th. on the contact of the air; the materials ferment in proportion to the free access of the air.

At the same time that they ferment the ex-

pressed grape with the view of fitting it for the production of verdigrise, they prepare the copper plates which are to be employed for the first time, by rubbing them over with a piece of linen, dipt in a solution of verdigrise, in an earthen pan. They are immediately extended by the side of each other and left to dry. Sometimes the plates are laid over the fermenting liquor, or placed one above another in that which has been already employed, in order to dispose them for oxydation.

We have already observed, that if the plates are not subjected to this kind of preparation or washing, they will become black instead of green by the first operation.

When the plates are properly disposed, and the materials in a state of fermentation, with the view of ascertaining whether it be a proper period to proceed to the remaining part of the operation, one of the plates is put into a vat and allowed to remain in it for twenty-four hours. If at the termination of this period we observe the plate covered with an uniform green layer, so that the copper does not appear, we judge it to be in a proper state to proceed; but if on the contrary, drops of wa-

ter hang on the surface of the copper, the workmen say that the plates *sweat,* and conclude that the heat of the fermented mass has not been sufficiently diminished, on which account another day is allowed to pass before making a similar trial.

On ascertaining that the materials are in a proper state, they proceed to form the strata in the following manner:

They place the plates in a vat, separated in the middle by a wooden grating, parallel to the bottom on which the plates rest; a pan full of live coals is placed underneath this grating, which heats them to such a degree, as sometimes to oblige the women, who manage this part of the work, to lay hold of them with a piece of cloth to prevent their hands from being burnt. When the plates have attained this degree of heat, they are put into the earthen vessels, so as to form alternate strata with the fermented materials, the upper and under layers being composed of the expressed grapes. The vessels are then shut with their straw covers, and left at rest. From 30 to 40 pounds of copper is put into each vessel, according to the thickness of the plates.

At the termination of ten, twelve, fifteen, or twenty days, they open the vessels, and readily ascertain if the operation be completed by the materials having become white.

Detached glossy crystals are then perceived on the surface of the plates; when the grapes are thrown away, and the plates put aside for future operations. For this purpose they are placed in a corner of the cellar, one against the other upon pieces of wood laid on the ground; at the end of two or three days they are moistened by taking them between the fingers and dipping them into a vessel of water, after which they are replaced in their former situation, where they remain seven or eight days, and are again subjected to immersion as before. This alternate moistening and drying is performed six or eight times at regular intervals of seven or eight days.

As these plates are sometimes dipt into wine, the workmen term these immersions *one wine, two wines, three wines,* &c.

By this process the plates swell, become green, and a stratum of verdigrise is formed on their surfaces, which is readily scraped off by means of a knife.

At every operation each vessel yields from five to six pounds of verdigrise. In this state it is termed *fresh,* or *humid verdigrise,* and is sold by the manufacturers to wholesale dealers who dry it for exportation. In this first state it is in the form of a paste which they carefully knead in wooden troughs, and afterwards put into leathern bags a foot in length by ten inches in diameter. These bags are exposed to the sun and air until the verdigris has attained a sufficient degree of dryness, when it is termed *dry verdigrise.* It loses 100 per cent. of its weight by this operation. They say *it is knife proof,* when this instrument plunged through the leather bag cannot penetrate the loaf of verdigris.

The copper plates employed in its formation are not thrown aside till they are completely corroded by the repeated action of the verjuice. In place of the artificial heat mentioned above, they are sometimes merely exposed to the heat of the sun: the same plates sometimes last for ten years, but they are frequently worn out at the end of two or three. This, however, depends in a great measure on the quality of the copper; that which is uniform, well hammer-

ed, and very compact, is considered as the most valuable.

Formerly the *wet verdigrise* could not be sold until its quality had been previously proved; and for this purpose it was entered at a public magazine, where it was sold after verification.

It is perhaps to this regulation that Montpelier has been enabled to maintain a superiority in the commerce of this article for several centuries. This is a species of protection which secures to the consumer on the one hand, a pure and faithfully prepared article, and to the honest manufacturer on the other, a certain sale for the product of his labours.

From the period at which all kinds of controul ceases, we observe abuses of every kind rapidly multiply; the consumer formerly secure respecting the purity of his materials, is now in daily dread of suffering by the cupidity and cunning of those with whom he deals. His art, so to speak, is now in his own hands only a discouraging alternation of success and failure*.

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* I speak here only of regulations which tend to secure the purity of those products, a knowledge of which cannot

On a comparison of the process described by Montet, with that I am about to mention, it will clearly appear that all the changes which have taken place are in favour of the new method.

Formerly they took the grape stalks which had been dried in the sun, and dipt them during eight days into the residuum of wine, distilled with the view of procuring ardent spirits. They were then placed in baskets to drain, after which about four pounds were put into an earthen vessel, upon which were poured three or four pints of wine. The stalks were strongly impregnated with this wine by frequently turning and pressing them down with the hand; after which the vessel was covered and the materials left to ferment. The fermentation commenced sooner or later according to the nature of the wine and the temperature of the air; but when once begun, the wine became turbid, and exhaled a strong

be obtained by simple inspection. I would be the last to propose any restrictions on their preparation; since such restrictions would be wholly subversive of all industry.

acetous odour; in fine the heat lessened, on which they withdrew the stalks and poured off the wine. When the stalks had drained a little, they disposed them in alternate strata with copper plates, and the operation proceeded in the same manner as when the expressed grapes were employed.

When the plates were taken out of the vessels in order to be put aside, in place of dipping them in pure water, as is practised at present, they moistened them two or three times with the residuum of the distillation of wine as already mentioned, and this is what was termed by the workmen giving them three or four *wines*.

We have already observed that great economy has been introduced into these manufactures by leaving off the use of wine, which considerably enhanced the price of verdigrise. It was at first objected to the new method that by it the copper was too quickly destroyed, but this objection fell to the ground of itself, when it was seen that the quantity of verdigrise obtained was in proportion to the erosion of the copper; and what affords a convincing proof of its superiority is, that this method is

now universally adopted by all manufacturers, to the exclusion of the former practice.

The manufacture of verdigrise at Montpelier is not a weighty concern, as it does not require an expensive apparatus; a few earthen vessels forming the whole furniture of the workhouse, it is become, so to speak, a domestic operation. In most houses there is a verdigrise-cellar; and it is by the females of the family that the principal operations are conducted. In the intervals of their other household concerns, they usually find time to attend to their cellar, and sometimes derive considerable profit from the product of their labours; it forms indeed a more valuable resource as it is attended with no kind of risk whatever. The female proprietors of these small works consider the scraping off the verdigris, and forming the strata, as the chief and most difficult part of the operation.

It will readily be perceived that this mode of manufacturing verdigrise would be incompatible with large establishments. They would certainly miscarry if carried on at the same time with these small manufactures, where the

profit is only regarded as an auxiliary resource, and the labour as an amusement.

It would besides be impolitic, and very unfortunate for society, were this branch of trade to centre in the hands of a single capitalist, which at present tends, by a variety of channels, to give life and activity to a numerous population.

The mode of preparing verdigrise would unquestionably admit of some improvement. For example, the acetification requires a warmer temperature than what is produced in the earthen vessels; it would therefore be necessary that this part of the process should be conducted in a separate apartment. The plates when set aside to generate the verdigrise, require a different degree of heat and humidity from that which is requisite for the other operations. But I have always thought that in order to produce these changes, it would be necessary to withdraw these establishments from that portion of the people in whose hands they are at present, and to whom it is sufficient to possess a small cellar, or one under a stair-case, in order to establish a manufacture which affords them the means of subsistence.

After dissolving the crude verdigrise in distilled vinegar, and concentrating the solution until it shoots into crystals, it takes the name of *crystallized verdigrise*, or *crystals of Venus*.

These crystals were for a long time prepared in Holland, but at present they are produced in such perfection at Montpelier, as to be preferred to those of foreign manufacture. The process usually employed for this purpose, consists in dissolving the verdigrise in distilled vinegar, and evaporating the solution till a pellicle appears, in order to hasten the crystallization.

They employ in general the residuum from the distillation of wines, which they allow to become sour, and afterwards distil.

This distilled vinegar is poured into caldrons, and boiled on the verdigrise. As soon as it is sufficiently saturated, the liquor is left to repose, and afterwards transferred into another copper caldron, in which the evaporation is performed. When the solution is sufficiently concentrated they plunge into it rods, which are fastened by means of packthread to wooden bars, supported by the sides of the caldron.

These sticks are a foot in length, and cleft across to within two inches of the superior extremity, in such a manner that they devaricate into four branches, which are kept asunder by small pegs. The crystals attach themselves to the surfaces of these sticks so as to exhibit the appearance of a cluster, presenting on all sides perfect rhombs, of a deep lively blue colour.

Each cluster weighs from 5 to 6 lbs. The fracture of these crystals is of a brilliant green, very beautiful, and inclining towards blue.

It requires nearly 3 lbs. of moist verdigrise, to produce 1 lb. of the crystals.

The residuum deposited by the solution was formerly rejected as useless; but having discovered on analysis that it contains much copper in a metallic state, or in that of a very weak oxyd, I took such means as were proper to oxydize this residuum, and have derived from it very great advantages.

This process though simple, appears to me to be susceptible of very great improvements.

The following are the results of several of these experiments:

1. Copper may be oxydized by the vapours of the oxy-muriatic acid, and the oxyd dissolved by the acetic acid.

2. The sulphuret of copper strongly calcined yields a residuum soluble in vinegar, and susceptible of forming with it an acetate.

3. The acetate of lead decomposes the sulphate of copper dissolved in water. The sulphate of lead is precipitated, and the acetate of copper remains in solution, from which *crystals of copper* are obtained by decantation and evaporation.

The distillation of acetate of copper furnishes very strong condensed acetic acid, known under the name of *radical vinegar*.

The crystallized verdigrise is preferred to the other in the composition of colours, and as a mordant in dyeing.

CHAPTER XV.

Of the Combinations of the Oxalic Acid.

THE oxalic acid is capable of combining with almost every known base; it forms an insoluble salt with lime, and precipitates it from all the acids, so that it constitutes an excellent re-agent to discover the presence of this earth in combination with solution.

The oxalate of ammonia, however, is preferable for this purpose, because it acts much more powerfully.

SECTION I.

Of the Combinations of the Oxalic Acid with Potash.

This combination, which Scheele, Westrumb, and Hermstadt discovered to be com-

posed of potash and the oxalic acid, forms what is termed the *oxalic acidule,* or *salt of sorrel.*

This salt is not formed artificially in our laboratories, because it is found more economical to extract it from the plant, the name of which it bears.

Boerhaave appears to have been the first who described the process by which it may be procured from the plant which contains it: he tells us that we ought to add to the expressed juice of the *rumex acetosa,* six times its weight of rain water, that it may readily pass through a linen cloth; that then the liquor must be evaporated to the consistence of cream, and exposed in a cold place, after covering it with a stratum of oil, in order that the crystals may be precipitated by rest.

Since the days of that celebrated chemist, Margraaf, Bayon, Savary Wenzel, Wiegleb, and Baunach, have furnished us with many important facts relative to the formation of this salt.

It appears that, for a long time, this salt was procured from the juice of wood sorrel, *oxalis acetosella*; but now it is for the most

part obtained from the *rumex acetosa foliis sagittalis* of Linnæus.

We are indebted to Baunach for some interesting observations, not only on the mode of cultivating this plant, in that part of Swabia known under the name of the *Black Forest*, but also on the manner of extracting and purifying this salt.

They sow the sorrel in March, and cut down the plant in June.

The plants are bruised in a large wooden mortar, by means of a hammer or pestel moved by water, after which they introduce the juice and the remains of the vegetable into wooden tubs.

After mixing this juice, and the remains of the vegetable in pure water, they leave them to macerate during some days, and then subject the whole to the action of a press.

When this operation is finished, the expressed matters are again bruised, adding occasionally a little water, and treating them as before.

For 1200 pints of the expressed juice, slightly heated, and put into tubs, are added 20 pounds of white and pure argillaceous

earth, after which the whole is agitated, and left to settle for 24 hours.

At the expiration of this period, the clarified juice, which swims on the surface, is poured off, and the matter deposited passed through a filter; after which they transfer the clarified juice into a tinned copper, and evaporate it till a pellicle appears on the surface of the liquor.

The juice thus concentrated is introduced into earthern vessels, that it may shoot into crystals.

These are afterwards purified by subjecting them to repeated solution and crystallization.

The mother water contains a portion of the muriate and sulphate of pot-ash. One pound of this plant, according to Baunach, yields;

oz.	dr.	gr.	
0	1	0	Pure salt of sorrel.
0	0	4	Muriate of pot-ash.
0	0	0¼	Sulphate of pot-ash.
4	0	0	Extract.

According to Savary, 50 pounds of the *oxalis acetosella* furnished 25 pounds of juice, which yielded 2 oz. 4 dr. of salt.

This salt crystallizes in prisms, united at one of their extremities, and divergent at the other.

Wiegleb describes them as forming elongated rhombs, lying one over the other. According to Delisle, they assume the form of long parallelopipeds.

This salt is soluble in six times its weight of boiling water. But its solubility varies according to the purity and the proportion of its constituent parts. According to Wenzel, 675 parts of this salt are soluble in 960 parts of water, at 212 degrees.

This salt is applied to the same purposes as the acid, but its effects are less marked.

CHAPTER XVI.

Of the Combinations of the Boracic Acid.

The only combination of this acid at all employed in the arts, is the *borate of soda,* or as it is more frequently termed, *borax.*

SECTION I.

Of the Combinations of the Boracic Acid with Soda.

Although borax has for a long time been an article of traffic, there is scarcely any production with the origin of which we are less acquainted; but notwithstanding the obscurity in which the history of this salt is involved, yet there are some facts respecting it too well authenticated to permit us to call them in question.

The *nitron baurake* of the Greeks, the *bo-*

rith of the Hebrews, the *baurach* of the Arabians, the *boreck* of the Persians, the *burach* of the Turks, the *borax* of the Latins, all appear to express one and the same substance, the *borate of soda*.

Two kinds of borax are distinguished in commerce, viz. crude and refined borax.

The quality of the first varies in proportion to its purity, and the place from whence it is obtained. In commerce two kinds of it are known. The one is brought by sea from Gomnon and Bengal, the other by land from Bender to Bassy, to Ispahan, and even Gihlan, whence it is sent by the Caspian Sea to Astracan, and thence by land to Petersburg, and from this last place to different parts of Europe.

The first is in a very impure state, and held in little estimation; but the second, which is brought by the caravans of the East, is composed of hard and greenish crystals.

In comparing what different historians have related respecting the origin and extraction of borax in Persia, Mogol, and Thibet, they appear all to agree that this salt exists in certain wells and lakes, and is extracted from them by

evaporation. This is proved by the testimony, first, of Bennet, a surgeon of the East India Company; second, by that of Saunders, who accompanied Governor Hastings in his journey into Thibet.

In the account given by Saunders we are informed, that the lake from which the borax is procured, lies fifteen days journey to the north west of Tissoolembo; thirdly, by that of a naturalist, who, in 1766, furnished M. Valmont de Bomaire with a particular account of the borax of India.

It should seem moreover, from the relation given by Grill, in the Memoirs of the Academy of Stockholm for 1773, that in some parts of Thibet they excavate the ground to the depth of six or eight feet, and thus procure the salt in different degrees of purity.

A traveller presented M. de Bomaire with a piece of native borax, which he affirmed is frequently found in beds in different caverns in Persia, and which is of a whitish colour, extremely alkaline to the taste, somewhat sweet, and less insipid than common borax.

A citizen of Dresden discovered, in 1755, in the Electorate of Saxony, a mineral earth,

which yielded a product fit for the purpose of soldering.

Borax has also been found in Spanish America. We owe this discovery to Dr. Carrera, a physician, settled at Potosi. In the mines of Riquintipa, near Escapa, it is found in great abundance. It is employed as a flux in the copper mines.

In its impure state, it is called tincal, in Thibet.

For the most part the borax, in a crude state, is stained with a kind of greasy matter, with which it is incrusted.

Crude, like purified borax, appears in hexangular prisms, somewhat flattened, and terminated by dihedral pyramids. The crystals, when broken, appear shining, and of a greenish hue.

The process for purifying borax was long confined to the Venetians; but the commerce with the Levant having been interrupted, in consequence of the war carried on for such a length of time between the Turks and the Persians, the trade fell into the hands of the Dutch, who continued to monopolize it, till

very lately, when establishments of the same kind were formed at Paris.

Tincal is not very soluble in water, a circumstance which seems to depend on the greasy matter united with it. It is owing to the presence of this principle, that it passes with difficulty through filtering paper. I have found, that 10, or 15 parts of boiling water, are necessary to dissolve it completely. By exposure to cold alone, and a proper concentration of the solution, it shoots into lamellated crystals, which require to be still further purified by solution, and filtration, in order to give them the requisite degree of whiteness.

By this means we separate the super-abundant and uncombined portion of the principle which remains in the mother water, and from the earthy impurities which the tincal, in a greater or less proportion, alway contains.

It appears that the Dutch content themselves with digesting the tincal in hot water for eight days; and after purifying it by colature, and concentrating the solution by means of a moderate heat in leaden cauldrons, set it aside to shoot into crystals, in vessels of the same metal, which they surround and cover

carefully with straw, in order to support the heat for a considerable time. It is not till after the lapse of fifteen or twenty days, that they remove the crystals which are formed.

This process, which I myself have frequently repeated, is extremely accurate.

By this method we obtain a borax equally pure as that which is regarded in commerce as of the best quality; but it is of consequence that the solution should be subjected, for several days, to a degree of heat approaching the boiling point, and regularly maintained without agitating the liquor; thus there will be precipitated a great portion of the extraneous matter with which the borax is intermingled; and beautiful crystals be obtained by evaporation, without the necessity of previous filtration.

In general, there may be obtained seventy-five, or eighty pounds of pure borax from each quintal of the tincal, or made borax.

The process here described for the purification of borax is the most simple, and the least expensive of any with which I am acquainted. I have also employed others; but though they do not appear to me to be superior, I yet

think it proper to describe them, with a view to prevent a loss of time to those who might otherwise be induced to try them.

1. Crude tincal dissolved in a weak solution of soda, and properly concentrated by evaporation, yields beautiful crystals. The product even exceeds, by five or six per cent., that which is obtained from the process already mentioned But the borax procured by this method slightly effloresces in the air, a circumstance indicative of an excess of soda. It did not, however, appear inferior as a solder.

2. We may destroy the greasy principle of the tincal by calcination, and facilitate by that means the solution of this salt. In 1779 I made these experiments, but it has been since pointed out, that there was an enormous loss sustained by this process, which has prevented me from publishing the results, though I have publicly mentioned them in my class.

Although the solutions of calcined tincal be more free from impurities, and much more readily pass the filtre than those of the uncalcined tincal, yet these last yield finer crystals than the former.

There are two sorts of purified borax sold in commerce; the one is termed Dutch borax, and the other Chinese borax; they are both manufactured in the same places; but the former is the product of the first crystallization, while the second is furnished by the last. The first consists of beautiful detached crystals, about one inch in length, and nearly of an equal diameter. They are white, semi-transparent, and of a greasy fracture. The form of the crystals is that of a six-sided prism, somewhat flattened, and terminated by trihedral, sometimes by hexahedral pyramids.

The second is composed of lamellated crystals, covered with a mealy or farinaceous powder, which seems to be of the nature of argil.

Borax is of a styptic taste, and changes the syrup of violets to a green colour.

Exposed to the action of heat, it swells, loses its water of crystallization, and is reduced into a white, light, friable, and opaque mass, in which state it is termed calcined borax. If a more violent heat be applied, it assumes the appearance of paste, and at last melts into a transparent greenish yellow glass, soluble in water, and effloresceing in the air.

This salt is soluble in 18 parts of water, at 60 degrees of Fahrenheit, and in 6 at 212 degrees.

Borax is one of the most active fluxes known, and is therefore frequently employed to ascertain the degree of fusibility of certain bodies, or to accelerate the vitrification of other substances. It is also highly useful in soldering metals, cleansing their surface, and assisting the fusion of the solder.

The property which borax has, however, of swelling on exposure to heat, renders its employment, in a crystallized state, difficult, since the intumescence tends to displace the pieces of metal intended to be united, and thus frustrates the views of the artist. This inconvenience may, however, be partly obviated, by calcining the borax, and employing it only when beginning to vitrify.

When the pure earths are exposed with this flux in clay crucibles, under the muffle of a cupelling furnace, to a heat from 22 to 26 degrees of Wedgwood, and kept up during two hours, the following are the results.

1. One part silica, and two borax.

A beautiful, pure, and transparent glass.

2. 1 alumine, 2 borax.

A beautiful transparent glass, of a vivid green, cracking on being withdrawn, from its adherence to the crucible.

3. 1 lime, 2 borax.

A beautiful transparent glass, with a slight yellowish tint. The crucible appearing to have been much acted on in every part with which the mixture in fusion had come into contact.

4. 1 magnesia, 2 borax.

A semi-transparent glass, of a milky colour, having the appearance of a jelly, extremely hard, separating into large fissures on being withdrawn from the crucible.

5. 1 barytes, 2 borax.

Beautiful glass, perfectly transparent, colourless, excepting a slight yellow tint, not cracking, adhering to the crucible, and h a enough to resist the point of a knife.

Borax determines the fusion of most substances, even of those which prove refractory to the action of oxygen gas. We have a striking example of its influence in the preceding experiments, from which it appears, that the fusion of silica was effected by it, at the 22d degree of Wedgwood, while this cannot be accomplished by oxygen gas, but with a degree of heat corresponding to the 4043d degree of a similar scale.

In all metallurgic and docimastic operations, the fusion of metals, and metallic oxyds, the most refractory is determined by mixing them with a small portion of borax, and other bodies, which readily pass into a state of fusion, or disengage the oxygen from the oxyds which we wish to reduce.

In this case, as soon as the matter is fused, and liquefied by exposure to an intense heat, it is left gradually to cool. The metal, as being most heavy, falls to the bottom, while the vitrified flux remains on the surface.

I have seen borax used with astonishing success in glass-houses, particularly when very refractory sands, or alkalies of a bad quality

had been employed. For this purpose, it is sufficient to mix carefully with the composition contained in each pot, a few ounces of borax. The matter then readily melts, and forms a consistent paste, which is easily refined, and blown without trouble.

In short, borax may be employed with advantage, in every case, when the object is to facilitate the fusion of any kind of matter. It remains united with the earths and metallic oxyds, with which it forms the vitreous masses. It concretes in a vitriform stratum above the metals, the fusion of which it has accomplished. It dissolves and enters into combination with all saline substances, producing saline compounds.

Its use would unquestionably be still more prevalent, were it more common; but its scarcity has so enhanced its price, that it cannot be employed as a flux on a great scale, and in works, the product of which is comparatively of little value. Besides, during war, a regular supply of it cannot without difficulty be obtained; on which account, I shall here mention some formulæ, by means of which the

use of borax may, to a certain degree, be superseded.

1. We are indebted to Georgi for the following process.

Natron is dissolved in lime water, and the crystals set aside which are deposited on the cooling of the liquor. The lixivium is then evaporated, and the residuum dissolved in the milk of lime ; this is also evaporated to an extract which is employed to answer the same purpose as borax.

2. Struve and Exchaquet have proved, that the phosphate of potash fused with a certain quantity of sulphate of lime, forms an excellent glass for soldering metals.

3. Pelletier has successfully employed the phosphoric glass well pulverised as a solder for silver.

4. Lemery proposes a composition prepared with nitre fixed by charcoal, alum, and urine. This mixture is evaporated to dryness.

5. The chrysocolla, mentioned by Dioscorides, which the ancients employed to answer the same purposes as borax, was evidently no-

thing more than a kind of solder prepared by the artists themselves, with the urine of children and the rust of copper pulverised in a copper mortar.

CHAPTER XVII.

Of the Combinations of the Prussic Acid.

THE prussic acid is of so volatile a nature that it can scarcely be obtained pure and free from extraneous matters; it forms very variable salts with different bases.

After the important discovery of the prussiate of iron, which is of all the combinations of the prussic acid that which is the best known, Macquer succeeded in separating it by other substances, under the name of the *colouring pinciple of Prussian blue,* without suspecting that it was a distinct and peculiar acid.

On distilling the prussiate of potash, the greatest part of the prussic acid passes into the recipient in solution with the water. This liquid does not change vegetable colours; when mingled with alkalies all the acids disengage it in an elastic form.

If the prussiate of potash be boiled on the oxyd of iron, it forms a new combination, possessing new properties, and which shoot into yellow crystals of an octahedral figure.

It is to the powerful affinity exerted by the prussic acid upon the oxyds, that we ought to refer the active acidity it assumes in this case.

As the only prussiate which is employed in the arts is that formed by the prussic acid with the oxyd of iron, we shall here confine ourselves to its consideration.

SECTION I.

Of the Combinations of the Prussic Acid with Iron.

M. Proust has given us a very interesting work on the different degrees of oxydation of metals, and having ascertained iron to be susceptible of two different states of oxydation, he asserts, that the prussic acid forms a white prussiate with iron in its lowest state of oxydation, and a blue prussiate with the oxyd of the same metal carried to its *maximum*.

M. Berthollet attributes this variety not so much to the difference in the degree of oxydation of the iron, as to the incomplete decomposition of the sulphate of iron, which takes place when the metal is slightly oxydized, because in this case the sulphuric acid is more adherent to its base. He founds his opinion upon this circumstance, that by weakening the mixture of the prussiate of potash, and sulphate of iron by the addition of water, it will become of a dark blue colour, having a greenish tinge; and by pouring an acid upon a white prussiate, the action of the prussic acid is augmented, and the colour changes into a blue. For this purpose the preference is given to the muriatic, sulphureous and phosphorous acids, which all produce this effect without its being suspected that they gave out oxygen to the oxyd. M. Berthollet repeated these experiments in flasks that were instantly shut lest it might be supposed that the atmospheric air furnished the oxygen, and he uniformly observed, that the white prussiate became blue by a mixture of the sulphuric, muriatic, sulphureous, and phosphorous acids.

M. Berthollet cannot deny, but that some

difference takes place between the prussiates in consequence of the state of oxydation of the metal. For example, that in which the iron is slightly oxydized is of a brighter blue, and not so quickly precipitated from the solution in which it is formed.

We shall next point out in what manner the combinations of the prussic acid with iron are produced in those workshops where they prepare the prussiate for the purposes of the arts, and where it is known under the name of *Prussian blue*. Before, however, entering on this part of the subject, it may prove interesting to give some account respecting the origin of this important discovery.

We learn from Stahl, that Dippel gave to Diesback, a manufacturer of colours, a quantity of potash upon which he had distilled animal oil. Diesback who was in the habit of precipitating the lake, from a solution of cochineal, alum, and a small portion of sulphate of iron by the aid of an alkali; having employed that given to him by the chemist of Berlin, was surprised at obtaining a blue precipitate. He imparted this result to Dippel, who in endeavouring to find out the cause,

discovered the means of composing, at a small expence, that beautiful blue dye, which from its origin, bears the name of *Prussian blue.*

This discovery was first published in the Memoirs of the Academy of Berlin for 1710, but the process was kept a secret till 1724, when Woodward published the account which he had received of it from one of his friends in Germany, in the Philosophical Transactions of London.

Until that period they had employed the charcoal produced by burning blood, in order to impart to the alkali the property of precipitating the iron of a blue colour; but Geoffry, a celebrated physician, demonstrated the following year, that the charcoal of all animal matters produced the same effect, and that even the vegetable charcoals possessed the same quality though in an inferior degree.

From this time the different chemists who turned their attention towards this phenomenon, strove rather to investigate the theory on which it depends, than to bring to perfection the process by which this dye is obtained.

It was in 1742, that the celebrated Scheele

succeeded in discovering the animal acid which is combined with the iron in the Prussian blue. This acid is now known under the name of the prussic acid; and it is for the most part extracted from animal substances, because it is present in them in the greatest abundance.

In all the different processes employed in the preparation of Prussian blue, the first step is to calcine the animal matters with the potash, in order that it may enter into combination with the acid contained in them; afterwards there is mixed together a solution of iron and of sulphate of alumine, with this prussiate of potash, in order to obtain the prussiate of iron, which always retains a portion of alumine and of potash.

But this process varies 1st. in the choice of the animal materials; 2. in the preparation of the alkali; 3. in the mode of calcination; 4. in the proportions between the sulphate of alumine and that of iron; 5. in the manner of heightening the colour.

1. Blood was the first, and for a long time the only animal material employed in this preparation, and it must be admitted, that there

is no other more advantageous in respect to the products which it furnishes.

But the difficulty of drying it on the one hand, and on the other the trouble of procuring a sufficient quantity of it any where but in large cities, at length induced manufacturers to substitute some other material in its stead.

Weber informs us, that in Germany they employ the horns, hoofs, and other parts of animals.

M. Guyton Morveau has shewn that the hides of oxen form a very good colouring lixivium.

Brown affirms that animal flesh answers the same purpose.

Delius, in 1778, mentions, that he found hair to answer as an excellent substitute for the dried blood; and he published in the Annals of Crel a paper, in which he states that horse dung succeeded very well for the same purpose, when the calcination was not pushed to too great a length, in which case the undigested fodder contained in the dung rapidly passed into the state of a pure alkali.

From Baunach we learn, that in the manufactures of Prussian blue established in Suabia,

they mix among the animal matters the cuttings of leather found in the shops of leather-sellers, sadlers, and shoemakers.

The fragments of leather found about tanneries, as well as the skin and flesh which is separated in dressing the hides may also be employed with advantage; but it is necessary to wash these matters with particular care, to deprive them of any particles of lime with which they may be impregnated.

Vegetable charcoal is sometimes also used in the preparation of this blue, as well as turf and coal soot, but these substances produce far inferior effects to those essentially animal.

2. According to the process published by Dr. Woodward in 1724, the alkali is prepared by the deflagration of equal parts of tartar and saltpetre. At present potash is universally employed.

3. Before this process had attained its present degree of perfection, the first step consisted in reducing the animal matters to a charry state, and afterwards calcining this carbonized matter with potash, in order to form prussiate of potash.

This method is still followed in many ma-

nufactories, where the animal charcoal and potash are mixed in very different proportions, according to the nature of the materials employed.

Baunach has seen this mixture formed of 10 lbs. of carbon, and 30 of alkali; but Weber relates that in some houses in Germany it is composed of 100 lbs. of potash and 75 of charcoal.

In other manufactures they distil the animal matters in iron cucurbits, in order to preserve the oil which is afterwards extracted; in this way they obtain oil, carbonate of ammonia, and charcoal; this last product is employed in the formation of Prussian blue, while the carbonate of ammonia forms the basis of a manufacture of ammonia, according to the method we have already described.

I have myself inspected some works in which blood and potash were mingled in equal proportions, and calcined in iron caldrons; I am even certain that the potash might be superseded with advantage by tartar, at least in respect to economy.

4. The employment of the sulphate of alu-

mine, and the sulphate of iron in the formation of Prussian blue is very general.

The alumine which in this case attaches itself to the prussiate of iron, renders its colour more delicate, and imparts to it the necessary degree of consistence in order to form a dry paste, which can be moistened at pleasure.

But these two sulphates are not always used in the same proportions. From Weber we learn that in Germany they employ six parts of alum to one of sulphate of iron. Baunach informs us that he has seen four parts of alum used to one and a half of sulphate of iron; and chemical writers in general recommend eight parts of alum and six parts of copperas.

From these facts it is obvious that the proportions are not uniformly the same, but vary according to the views of the manufacturer, and as he may wish to obtain a more or less deep blue. Thus, for example, when the blue is intended to be very bright, the proportion of the alum is augmented, and on the contrary diminished, when extremely full deep blue is the object.

5. In some manufactures, after having precipitated the iron and alumine by the prussiate

of alkali, a small portion of muriatic acid is poured on this precipitate to heighten the colour.

This acid not only concurs to render the colour more vivid, but to enable a greater portion of the prussic acid to act on the iron, by its tendency to separate from it the potash of the prussiate. It is attended with the further advantage of dissolving a small portion of the yellow oxyd which is precipitated from the iron without having entered into combination with the prussic acid.

From these general principles any one might be enabled to perform all the operations concerned in the formation of Prussian blue; but in order to render their execution still more easy, we shall proceed to describe the process followed in the manufacture of this article in Germany.

They calcine in iron caldrons, or distil in large iron cylinders, the horns, skin, and other animal matters, until they are reduced to a carbonaceous matter.

One hundred pounds of potash is then put into an iron caldron, and exposed to a very brisk fire until the potash be melted, when

25 lbs. of the animal carbon reduced to powder is poured into it, and the mixture well stirred and melted; at the termination of half an hour another 25 lbs. of carbon is added; and a similar quantity at the end of the next half hour.

When in this way the mixture is completed, they keep up the same degree of heat during several hours, constantly stirring the paste with an iron spatula.

During this process a reddish white flame appears on the surface, which gradually diminishes, and is succeeded by a feeble blue flame, a circumstance which indicates the propriety of terminating the calcination. During the whole of this operation the strength of the fire ought to be such as to preserve the matters at a red heat.

This substance while still red hot, is removed from the caldron, and extinguished by plunging it into a copper full of boiling water. The first water is then decanted off, and the residuum transferred into a caldron, where it is boiled during half an hour with a fresh supply of water. The lixivia are then filtered through thick flannel or linen cloths.

This solution is termed the *colouring lixivium, phlogistic alkali,* or the *solution of the prussiate of potash.*

Two hundred pounds of alum and copperas are next dissolved in a sufficient quantity of water; the proportion of these two salts being varied, as has been already mentioned, according to the shade of colour intended to be produced; and this solution is poured into the *colouring lixivium* through a cloth that serves the purpose of a filter.

From the mixture of these two solutions the blue deposition is quickly formed, after which the liquor is decanted off, and the precipitate washed in boiling water with the view of freeing it from all the salts not necessary in the composition of prussian blue.

The precipitate is then put into a cloth to drip, after which it is subjected to the operation of pressing, and dried in the shade or in a warm room to preserve its colour.

It is sometimes also washed with the muriatic acid.

The prussian blue is in general of a vivid rich colour. That which is light and not of a glossy fracture is esteemed the most valuable.

I procured from an ounce of Prussian blue distillation:

Ammonia -	1 dram 60 grains.
Hydrogen gas with a blue flame	164 inches.
Oxyd of iron	1 dram 30 grains.
Alumine -	2 drams 54 grains.

And a small portion of water.

In this operation the acid is decomposed by the action of the heat, and two of its constituent principles produce ammonia, while the other escapes in the state of hydrogen gas.

In order to form prussiate of lime, with which a test liquid is prepared, with the view of detecting any particles of iron present in a liquid, it is sufficient to wash two ounces of finely pulverized Prussian blue in boiling water; and pour into it two pints of lime water, boiling them together for a few seconds; after which the liquor is filtered and set apart for use. It is of a yellow colour, and its specific gravity only amounts to 1,005.

The prussiate of alkali is less certain, and

less rapid in its effects than that of lime. It besides contains a portion of oxyd of iron which is almost inseparable from it, and which necessarily produces a variation in the results; it is less sensible, and not so easily decomposed as the prussiate of lime, on which account this last deserves a preference in all operations requiring great delicacy.

CHAPTER XVIII.

Of the Combinations of the Gallic Acid.

THE gallic, like the prussic acid, does not possess a very marked acetous character; they are easily decomposed; but their combinations with certain bases, especially with iron, besides possessing properties which render them extremely valuable, oppose a greater resistance to destructive agents than the acids themselves.

SECTION I.

Of the Combinations of the Gallic Acid with Iron.

This combination termed *gallate of iron*, enters into the composition of ink, as well as into that of most of the black colours employed in dyeing.

Hence it is evident, that the gallate of iron

is one of the most useful and most extensively employed salts with which we are acquainted.

We shall only here treat of it as connected with the making of ink, as that which regards dyeing will find a place in the chapter appropriated to this subject.

The properties of good writing ink are the following:

1. A very black colour.
2. Flowing readily and uniformly under the pen.
3. Not penetrating into the substance of the paper.
4. Drying with rapidity.
5. Not acquiring a yellow hue on exposure to the air.
6. Not being effaced nor diffused by friction.

It is only by a complete knowledge of all the substances which enter into the composition of ink, that we are enabled to employ those means calculated to unite all the most desirable properties, and to discover the cause of those defects which are frequently found in this composition.

Among the ingredients which are employed in the preparation of ink, some are absolutely

essential, while others are used merely as accessories, with the view of imparting to it some property or meliorating its quality.

In the first class may be ranked gall-nuts and copperas, since on these substances its black colour wholly depends.

In the second may be placed gum, log-wood, sulphate of copper, alum, and sugar.

The excipient of the gallate of iron, which forms the essential base of ink is water, to which is sometimes added beer, wine, vinegar, or ardent spirits.

From the labours of Messrs. Lewis, Neumann, Monnet, Guyton, Scheele, Deyeux, Berthollet, Proust, and others, we have acquired a sufficiently precise knowledge of gall-nuts, to enable us to conceive the nature of the action they exert upon iron, and to assign to its proper cause the superiority of this substance over every other that has been substituted in its stead.

Gall-nuts are a vegetable excrescence, which owe their formation to the evolution of the larvæ of insects, and which consequently possess some characters approaching to those of animal productions.

They differ very essentially from astringent vegetables, such as tan, shumach, &c. in containing the gallic acid completely evolved, which M. Berthollet could not detect in these other astringent substances.

Gall-nuts are then possessed of two very distinct principles; tannin or the astringent principle, and the gallic acid.

The first of these principles is common to all astringent vegetables; the second would appear to be peculiar to themselves.

These two principles may be separated by a very simple process, which we owe to the labours of M. Proust. It appears to me indispensible to relate it in this place, though it has been already mentioned under the article *gallic acid*.

The process in question consists in precipitating the solution of gall-nuts, by a solution of tin in the nitro-muriatic acid, produced by the mixture of one part of muriatic acid with two parts of nitric acid. It forms an abundant yellow cream, which swims on the surface of a pale yellow liquor. It is carefully filtered, and the precipitate washed, which remains on the filter.

The liquor contains the gallic acid mixed with the muriatic acid, and muriate of tin.

The precipitate is composed of a mixture of tannin and tin.

The tin is precipitated from the solution in the form of a sulphuret, by the sulphuretted hydrogen gas ; and the gallic acid is afterwards obtained in crystals by evaporating the liquor.

By diffusing in water the oxyd of tin combined with tannin, the sulphuretted hydrogen gas seizes on the tin, and the tannin being thus disengaged is dissolved in the water.

By filtration and evaporation an extract is formed, consisting of pure tannin, which may be preserved by dissolving it in alcohol.

Tannin precipitates iron of a blue colour.

The gallic acid precipitates iron of a black colour, when it is highly oxydated in the solution ; or when its action upon the oxyd of iron is assisted by weakening that of the sulphuric acid, by the addition of water or alkalis.

M. Proust is of opinion, that the iron is only precipitated of a black colour when at its *maximum* of oxydation, and he founds his opinion on the following principles :

1. That the infusion of gall-nuts does not precipitate the iron of a black colour from the green sulphate.

2. That the precipitate becomes black by absorbing oxygen from the air.

3. That the iron of the red sulphate is always precipitated of a black colour.

M. Berthollet differs in opinion from this celebrated chemist, and asserts, that whenever the iron is not precipitated of a black colour, it proceeds from the gallic acid not having exercised a sufficiently powerful action on the iron to liberate a sufficient quantity of sulphuric acid; but, that on weakening the affinity of this last acid, by adding to the solution of the sulphate a little water, or a small portion of alkali, the black hue immediately appears. He supports this opinion by several direct facts, which prove that the gallic acid, when boiled on iron in close vessels, or digested with it cold, produces a black gallate, in every respect similar to the precipitate of iron, from the acetate of this metal by the gallic acid.

From all these facts M. Berthollet concludes

that it is not necessary to the production of a black colour in the precipitate, that the iron should have attained its *maximum* of oxydation. He does not however deny that highly oxydated iron may produce a deeper black, and he attributes to the gallic acid the property of partly de-oxydizing the metal, and reducing it to the state of an *ethiops*.

This assertion assumes the appearance of truth, when it is recollected that gold and silver are precipitated in a metallic state by the gallic acid.

Tannin cannot be regarded as wholly useless in the composition of ink, since it forms with the iron a blue precipitate.

We owe to the labours of the chemical class of the Academy of Sciences at Paris, a very accurate comparative statement of the effects of the most common astringents with the sulphate of iron.

These experiments, which were made in 1793, prove:

1. That in equal weights of gall-nuts and oak bark the former contains at least forty times more of the astringent principle than the latter.

2. That the precipitate obtained from gall-nuts is of a deep violet colour, while that from oak bark is of a dark brown, and that the first resists much longer than the second, the action of acids.

3. That it requires 800 pounds of oak-bark to produce the same effect as 20 pounds of Aleppo galls.

4. That oak saw-dust is preferable to the bark.

5. That gall-nuts, in common with all the other astringents, possess the advantage of being almost wholly soluble in water; the residuum, amounting only to one-eighteenth, after long continued ebullition.

Though it appears proved from the experiments of the chemists already mentioned, that in dying wool, the place of the gall-nuts may be supplied by a greater or less quantity of some other astringent, yet it is equally true, that no substance we are acquainted with, can act as a substitute for them in dying thread and cotton, nor in the preparation of ink.

In order to convey a more clear idea respecting the action of gall-nuts on iron, I shall

relate the following experiments made by myself.

1. If we pour a single drop of the decoction of gall-nuts on an iron plate, it instantly blackens round the borders; and the whole spot gradually acquires a full shining black colour. In proportion to the evaporation of the liquor the spot becomes wrinkled at the surface, and finally falls down into a black powder.

2. If a decoction of oak, or any other astringent, be employed instead of that of gall-nuts the colour will be much less black.

3. If the iron, thus coloured, be plunged into water, the spots produced by the gall-nuts will become quickly covered with bubbles, which burst at the surface, and which Priestley, long ago, ascertained to be hydrogen gas.

The iron coloured by other astringents, precipitates a yellow powder, without the appearance of a single gazeous bubble.

4. If a decoction of gall-nuts be poured on filings of iron, and covered, the liquor becomes gradually coloured, the iron blackens, and we obtain in the course of a few days a very black ink.

Any other astringent decoction, treated in the same manner, is not sensibly coloured.

Here we have an additional proof of the agency of the air upon oxydation, when acting in conjunction with an acid; for, if the iron be only moistened by the decoction, a very good black colour is produced in the course of a few hours; but on the contrary, if it be perfectly covered with the liquid, several days are required to produce the same effect.

5. When the action of the decoction of galls is assisted by heat, carbonic acid gas, and hydrogen gas is evolved; but I have uniformly found, that the carbonic acid exceeded the other. There remained in the cucurbit only black iron mingled with charcoal highly pyrometrical. In this case the acid is decomposed.

It follows from these experiments, that the decoctions of astringent vegetables act upon iron in the same manner as acids. They even oxydize it to such a degree, that it passes into the state of an *ethiops*.

It appears further, that the carbon is liberated by the action of oxygen upon astringent decoctions.

In order to form a correct conception of this

last phenomenon, it is proper to mention that, indigo excepted, gall-nuts of all other vegetable substances furnish the greatest portion of carbon, so that when oxygen is brought into contact with the decoction, it forms water with the hydrogen, and the carbonate is mostly set free. Hence it is evident, why all the decoctions, and the most extracts of astringent vegetables, blacken in contact with the air, and why the compositions for dying black improve by keeping, and exposure to the atmosphere.

From what has been said, it must be evident, that gall-nuts should be preferred, to all other astringents, in the formation of ink.

But all the galls of the shops cannot be indiscriminately employed, with equal success, for this purpose; the white light gall-nuts of Spain and the south of France, are of a very inferior quality, as well as the thorny gall-nuts. The preference ought therefore to be given to the very heavy black galls, or at least to a mixture of black and white galls, known in commerce under the name of *sorted galls*.

The same care ought to be taken in our choice of the combinations of iron. The sul-

phates and muriates are decomposed with greater difficulty by the gallic acid than the acetates. The latter ought therefore to be preferred; but as this last salt is never in a crystallized state, which renders it difficult to determine the proper proportion; and as besides it has not hitherto formed an article of commerce, the sulphate is at present generally employed.

As, however, the sulphate of iron does not yield a black precipitate with the gallic acid, and as some time must elapse before it acquires that colour, M. Proust was hence induced to propose as a substitute for it the red sulphate, in which the iron has attained its *maximum* of oxydation, and from which a beautiful black precipitate is obtained.

I have myself succeeded in imparting to the green sulphate at a small expence, and in a short time, all the properties of the red sulphate; for this purpose it is only necessary to calcine it to redness, and afterwards separate from it, by water, all that portion which remains soluble.

The solution carefully filtered, produces very superior effects to those of the green

sulphate, either with the gallic or the prussic acid.

A solution of the sulphate thus prepared, lost a great portion of red oxyd which remained on the filter, when the solution was passed through it. If we confine ourselves, however, merely to deprive the sulphate of the water of crystallization, and put a stop to the calcination, on its assuming a white colour, this preparation produces very little effect.

The solution in water of the sulphate, calcined to redness, is acid; it reddens blue paper, while the green sulphate produces on it not the least change; and if we even impart to this last the slightest acidity, it produces a worse effect than before.

Equal parts of the solution of calcined and green sulphates, of the same degree of concentration, and mixed separately with equal parts of the decoction of gall-nuts, produce very different effects.

The calcined sulphate gives a beautiful black colour.

The green produces one a dim violet.

The first colours white paper black.

The second leaves upon it only a brown stain.

A few drops of the solution of the calcined sulphate scattered over unsized paper, run into spots, which are uniformly black over their whole surface, while the solution of the green sulphate diffused over paper in the same manner, exhibits three different shades of colour, that of the centre which is black, that of the middle which is grey, and that of the edges which is nearly colourless.

The solution of calcined sulphate precipitates the alkaline and earthy prussiates of a fine blue colour; while that of the green sulphate forms with them a greenish blue precipitate, extremely disagreeable to the eye.

Potash, and the carbonate of potash, precipitate the iron from the calcined sulphate, in the form of a black oxyd; and that from the green sulphate in the form of a whitish grey oxyd, which becomes darker on exposure to the atmosphere.

Soda produces in these two sulphates less evident differences.

The results of these experiments ought not only to direct the makers of ink but likewise dyers, in regard to the composition of Prussian blue.

The proportions between the gall-nuts and the sulphate will powerfully influence the results. This truth is well known to all those who are engaged in such labours, though they greatly vary among themselves in respect to the proportions they conceive to be most proper; from 6 parts of galls to equal parts of the two principles that have been recommended; hence we see how difficult it must be to prescribe invariable proportions; they must indeed be different according to the species of the gall-nuts, the strength and age of the decoction, the nature of the copperas, and the quantity of water employed.

From experience we may form a very accurate estimate of the proper proportions by always using the materials of the same quality; but it is difficult otherwise to form a general standard that will uniformly produce the same results.

When the galls predominate in the composition of ink, the colour though durable is brown, and the fluid very soon becomes mouldy.

If, on the contrary, the iron be in excess, the ink is at first more blue, but becomes yellowish in time, and spreads upon the paper.

The first defect may be corrected by allowing the filings of iron to remain in the ink, or by adding to it a solution of copperas. The best remedy for the second is mixing the ink with a fresh solution of gall-nuts, or according to Mr. Blagden with the alkaline prussiates.

Lewis is of opinion that the best proportions between Aleppo galls and the copperas, is that of three to one.

M. Ribancourt employs them in the relation of two to one; but as it is well known that an excess of galls is not so prejudicial as that of iron, since the first renders the ink durable and indecomposable on paper, and that it gradually blackens more and more by keeping; while that an over proportion of the second renders it yellow and rusty; it is much better to exceed in the quantity of galls than in that of iron.

But however carefully these operations have been performed, they only produce a black liquor, very proper for dyers, but wholly insufficient to produce ink possessing its usual properties; this liquor when laid on paper penetrates its texture, flows too readily from the pen, and does not possess a sufficient body.

The greatest part of these inconveniences may be obviated by the addition of gum; this substance dissolved and diffused among ink, imparts to it consistency, prevents its spreading upon the paper, or sinking into it, renders it drying and glossy, and prevents the too rapid action of the acids or water, while at the same time it equally protects the iron from oxydation.

Gum arabic is usually mixed with ink, as the gum tragacanth renders it too consistent.

When the proportion of gum is too great it renders the ink thick and prevents it flowing freely from the pen; but if on the contrary the quantity be too small, the ink possesses the opposite inconveniences; it sinks into the paper, flows from the pen like water, and in short has all those faults which we mentioned as belonging to the dyer's liquor.

In order to ascertain with more precision, the effect produced by the employment of various proportions of the red sulphate with gall-nuts and an infusion of gum-arabic, I prepared a solution of the sulphate at 10 degrees of concentration, a decoction of gall-nuts at 3, and of the infusion at 15 degrees.

I combined these three substances in all possible proportions, and afterwards tried the product of each mixture, not only by writing, but by dipping ribbons of paper into them, which were left to dry, in order that I might be thus enabled to compare and study the changes produced on them by air and water.

From these experiments, conducted with the greatest care during four months, I was enabled to deduce the following results :

Composition or Mixture.	*Results.*
I. The three solutions mixed in equal parts or in equal bulks.	Composition blueish, blackening by keeping, and forming in time a good ink, without however, becoming perfectly black. The writing executed with this ink does not become so black as that kept in the bottles.
II. Two parts of the solution of iron. One part decoction of galls. One part mucilage of gum arabic.	Ink violet losing its colour on paper. Acquires little additional blackness in the bottles. Paper dipped into this ink assumes a dark grey colour.

Composition or Mixture.	*Results.*
III. Four parts solution of iron. One decoction of galls. One mucilage.	Ink violet. Losing part of its colour on paper, and changing to a greyish yellow. Blackening in the bottles.
IV. One part solution of iron. Two decoction of galls. Two mucilage.	Of a beautiful violet blue. Preserves its colour on paper. Improves and blackens in the bottles. Paper dipt in water preserves the ink of a fine blue colour.
V. One part solution of iron. Three decoction of galls. Three mucilage.	Blacker than any of the preceding numbers. Blackens very much in the bottles. Changing little on exposure to the air. It preserves nearly the same colour when the paper is dipt into water.
VI. One part solution of iron. Six decoction of galls. Six mucilage.	Brownish black. Paper dipt in it assumes a deep red black. Blackens little in the air, and very little in the bottles.
VII. One part solution of iron. One decoction of galls. Two mucilage.	Ink of a good quality, though somewhat blueish. Too thick. Blackens on exposure to the air, and in the bottles. Very glossy.

Composition or Mixture.	*Results.*
VIII. One part solution of iron. Six decoction of galls. One mucilage.	Ink of a brownish black. Too thin. Sinks into the paper. Does not improve much in the bottles, nor on exposure to the air.
IX. Four parts solution of iron. Six decoction of galls. Four mucilage.	Ink of a very dark blueish black, fit for immediate use. Flowing well under the pen. Improves in the bottles. Blackens on paper.

From the results of these experiments may be drawn many valuable practical deductions :

1. When the iron predominates the colour changes to a violet, and when used in a very great proportion it fades and becomes grey.

In all cases wherein the iron exceeds, in however small a degree the proper proportion, the colour preserves a deep blue.

2. When the galls predominate, the colour is at first of a browish black, which in time becomes a very deep black, displaying a slight reddish tint.

3. Gum employed in equal parts or in a greater proportion render the ink too thick, while on the contrary, if it be used in a less

proportion than that of one half in relation to the galls, the ink is too thin, flows too readily from the pen, and sinks into the texture of the paper.

4. The proportions which appeared to me to unite the greatest number of advantages, were :

Four measures of the solution of calcined sulphate at 10 degrees of concentration.

Six of the decoction of *sorted gall-nuts* at 3 degrees.

Four of the mucilage of gum arabic at 15 degrees.

The combination of the oxyd of iron with the astringent principle and the gallic acid, communicates the colour to the ink; the gum, while it renders it glossy, also imparts to it the body, or necessary degree of thickness.

Hence the union of these three substances in proper proportions forms good ink; but ink-makers have been in the habit of adding other ingredients, the effect of which it is of importance to appreciate and ascertain.

The first of these we shall notice is logwood. In order to ascertain its effect in the composition of ink, it is necessary to attend to the

mode of its action on the iron, and afterwards to the modifications it may produce in the combinations of the three principles we have mentioned above.

The decoction of logwood attacks the iron of the oxyd forming with it a blueish combination.

It precipitates the iron from the sulphate of a light blueish black colour. This precipitate remains a long time suspended in the liquor.

If we boil a mixture of logwood and gall-nuts, it always appeared to me that in order to attain the same result, it was necessary to employ a much greater proportion of the decoction.

Logwood, according to my experiments, contributes nothing towards the colour; but I have always observed, that the ink into the composition of which it enters, is of a somewhat stronger body, that the tint is more mellow, and the writing more distinct and perspicuous.

Hence I should suppose, that logwood by maintaining the precipitate in a state of suspension, renders by this means, the ink more mellow and flowing, and enables us to apply

it more equally, and with greater facility to the paper.

The best proportion between the logwood and galls is that of one to two.

The sulphate of copper is another ingredient which is always employed in the making of ink.

My experiments on this subject prove, 1. That the sulphate of copper employed in a twelfth or twentieth part by the weight of the galls, produces a good effect.

By this addition the violet-blue colour of recent ink disappears more quickly, and its impression on the paper is more permanent.

2. That if this sulphate be used in a greater proportion than a tenth, by weight of the galls it will partly destroy the colour, and cause the ink at length to contract a disagreeable pale greyish tint.

3. That this injurious effect of the sulphate of copper is in proportion to the greater quantity of the sulphate of iron.

The sulphate of copper may then be employed with advantage in the proportion of one fifteenth, by weight, of the galls.

Sugar is another material sometimes em-

ployed in the composition of ink, and to it is attributed the property of rendering it more glossy. My experiments, however, have not enabled me to perceive any advantages from the use of this article, which I am of opinion, should be wholly rejected.

Water, wine, beer, and vinegar, are the four liquids usually employed as a vehicle or menstruum to the constituent principles of ink.

Prejudice rather than an accurate investigation of the effects and properties of each of these solvents, has, I am convinced, been the cause of the preference given to one or other of them.

Some comparative trials which I instituted between these menstrua did not exhibit very great differences, and if any were observable, they were all in favour of the water.

Beer appeared to me the worst vehicle of the whole, as it evidently favoured the natural tendency of the ink to become mouldy.

Vinegar seemed only useful for correcting ink which had acquired a yellow colour, or when the iron was in too great a proportion.

From all that has been said we may therefore conclude, that in order to compose good

ink, two parts of *sorted gall-nuts* previously pounded, must be added to a third part of logwood in chips.

These two substances must be boiled in twenty-five times their weight of water, and the ebullition supported during two hours.

If the evaporation be too powerful, a little water must be added in order to support the ebullition.

This decoction will usually be found of from three to three and a half degrees of concentration.

The gum arabic well pounded must then be dissolved in tepid water until it be saturated. This mucilage will mark from 14 to 15 degrees.

At the same time must be prepared a solution of calcined sulphate concentrated to 10 degrees, and in which is dissolved sulphate of copper in the proportion of one fifteenth, by weight of the galls employed.

These preliminary operations being completed, the next step of the process is to mingle six measures of the decoction of gall-nuts and logwood with four measures of mucilage.

Into this tepid mixture must be gradually poured three or four measures of the solution

of the calcined sulphate; taking care to stir the liquor during the whole time.

This process has the advantage of producing good ink free from any sediment.

From some experiments, instituted with a view to discover the precise quantity of matter really contained in each of the three solutions which concur in the formation of this ink, I found them to be in the following proportions:

Dissolved gum	500 parts.
Dissolved galls	462
Oxyd of iron	481

If we find on trial, that this ink is either too thick or too watery, these defects may readily be corrected by the addition of a portion of water or mucilage according to circumstances.

When the colour is too much inclined to blue, we may deepen it by pouring in a small portion of the decoction of galls.

If, on the contrary, it has a greyish or reddish tinge, the addition of a little of the solution of iron will correct these imperfections.

The colour of inks injured by keeping, may be restored by a decoction of gall-nuts, accord-

ing to Lewis; and by the prussiate of potash, according to Blagden.

Since it was discovered that the oxy-muriatic acid possessed the property of dissolving ink, and discharging it from paper without injuring its texture, or acting on the new writing, the secret has been abused for the purpose of defacing writings and substituting others in their stead, by leaving the original signatures untouched.

These frauds have rendered the government anxious that some composition could be discovered to replace the common ink, which would not be liable to this disadvantage.

Having been occupied for some time with respect to this object, I am inclined to believe that the purpose in question will be best answered by dissolving isinglass in water until the liquid acquires the thickness of common ink, after which lamp-black and a small portion of muriate of soda must be carefully levigated on a marble slab along with the solution, adding a sufficient quantity of the black powder to impart to it a good colour.

This composition has been found to answer very well in practice; it resists the action of cold and boiling water, as well as that of alka-

lies, acids, and alcohol. It is only attended with the inconvenience of being injured by friction.

We may also employ China ink with the same intention; or may even mix these compositions with common ink, as in that case the muriatic acid does not wholly destroy the colour.

There is a preparation known in commerce under the name of *China ink*, which is usually composed of lamp black reduced into a paste by gums or mucilages, and afterwards formed into tablets. But it appears that the genuine *China ink* is an inspissated substance or glue prepared from the cuttle fish: *Sepia piscis est, qui habet succum nigerrimum, instar atramenti, quem Chinenses cum brodio Orizæ vel alterius leguminis inspissant, et in universum orbem transmittunt, sub nomine atramenti Chinensis.*

In warm countries, such as Italy and the South of France, they employ the liquor of the cuttle-fish for the same purposes, and with the same success as the best China ink.

CHAPTER XIX.

Of the Combinations of the Carbonic Acid.

THE carbonic acid combines with the metals, alkalies, and some earths, and can form salts perfectly saturated, as M. Berthollet has demonstrated.

The two principal combinations of this acid are those with lime and with lead.

At present we shall not speak of the first of these combinations, as it has been already noticed when treating of the carbonate of lime or limestone, which we have considered in its relation to the arts. We shall now therefore treat of the carbonates of lead.

SECTION I.

Of the Combinations of the Carbonic Acid with Lead.

The carbonate of lead, termed also *ceruse, white lead,* &c. is produced by the combination of lead with carbonic acid.

These denominations are employed to express a white salt which is obtained by the oxydation of the metal, by means of the acetic acid, and by its solution in the carbonic acid. This salt is sometimes mixed with chalk, and this is what forms ceruse.

White lead has been demonstrated to be a carbonate by M. Bergmann.

The average of the analysis performed by Messrs. Bergmann, Chenevix, Klaproth, and Proust has established the following proportions between the two constituents.

15,87 acid.
84,13 oxyd.

This salt is not manufactured in any very considerable quantity in France; but there are three or four works of this kind in Belgium; the British and Dutch however monopolise the sale of this article.

I shall therefore describe the process employed in its preparation in these two countries, and conclude by offering a few observations on this subject.

In Holland and in England, particularly in

Yorkshire, they melt the lead by means of a very gentle heat, and pour it into iron moulds 2 feet in height by 4 or 6 inches in width; in some houses they cool the lead by dipping it in water, while in others this is not practised; they only take care that it be not poured into the moulds too hot, as in that state it is apt to adhere to their surface. In proportion as the lead diminishes in the caldron they put into it a fresh supply.

The leaden plates are of different degrees of thickness; seldom exceeding one half line, or at most one line.

The pots intended to receive these plates are from 7 to 8 inches in height, and from 2 to 3 inches in diameter; they are composed of earth varnished within and widest at the top. At one third of their height are three projecting points in the inside, intended to support the leaden plates.

The apartment in which the operation is performed, is a kind of hall, frequently open towards one of its sides, in which they form different compartments by means of pillars, which support strong platforms, intended to contain the beds in which the pots are placed.

Upon a bed formed in each compartment with straw, which has served as litter, and which is raised to about the height of three feet, and well trodden down, they dispose a range of pots as near to each other as possible, without stuffing the empty spaces with the dung. The pots are then filled with vinegar to the height of about two inches, so as to reach the projecting points already mentioned; after which a very thin plate of lead is introduced into each of them, rolled up in a spiral form, and supported on these projections. The pots are afterwards covered with plates of lead somewhat thicker than the former.

Upon this first stratum of dung they raise a second, of about one foot in thickness which is also trodden down with care in order to render it more compact; other pots are likewise arranged on this bed, and from five to seven beds are raised in the same manner, their sides and tops being covered so that each range of pots is surrounded with one foot of dung.

The beds are of such a size that each can receive six or eight hundred pots.

They are always placed against the pillars

of the wooden platforms in order to support the bed in proportion as it is raised, and the same precaution is used in demolishing them.

When the fermentation appears to languish, the beds are watered with the urine of horses, and the openings into the apartment closed up.

The pots are left in the beds during one month or six weeks.

At first the mass swells up from the great extrication of air; the fermentation in a short time however, is moderated, and remains stationary; the average heat of the mass is 40 degrees of Rheamur.

After taking the beds to pieces the plates are transferred to solid tables, where the white stratum formed on the surfaces of the lead is detached by striking them above with a hammer; care being taken to moisten the plates with water, in order that the oxyd may not be raised in powder.

The leaden plates with which the pots were covered, exhibit a more hard and compact crust; they are set apart in order to form *white lead, properly so called.*

The white substance from which the ceruse is to be formed, is put into a large wooden cistern with water, from which it is again taken in order to be ground by millstones, which do not differ from corn-millstones but in their size, which is smaller.

In some manufactures in Holland, three mills are placed one above another, in such a way that, in proportion as the ceruse has been ground in the first, it falls into the second, and from the second into the third, whence it passes into a receiving tub.

These millstones work three weeks successively, more or less, without stopping; and they may grind daily 15 cwts. of ceruse. It is in this operation of grinding, that there is added the proportion of chalk necessary to form ceruse. This is added in the proportion of from a fifth to a half of the weight of the oxyd.

White lead receives no mixture; it becomes an article of commerce in the form of small scales, and on that account is called *white scales.*

It is also called *white lead in scales,* when, after being ground, it is formed into small

white loaves, of which the fracture is scaly and shining.

The mill-stones used in Holland are of lava; they run in grooves to facilitate their motion, and prevent over-heating.

The matter thus ground is put into unglazed earthen pots, of a conical form, and four inches in depth. These are placed upon planks, regularly ranged one above another, in a long and narrow building. The light is admitted into the drying room by a number of windows, which may be shut at will by shutters moving on hinges, which close in from below to the top, in order to preserve the ceruse from the sun, and from too much moisture.

After remaining five or six weeks in the pots, the ceruse detaches itself from their sides, and the loaves are replaced upon the same planks, to finish the process of drying. It only then remains to take off the slime adhering to each loaf, with a knife.

The loaves are then wrapped up in paper, which is tied with packthread, and put into casks, to be conveyed all over Europe.

It has been attempted to substitute the heat of a furnace for that of dung; and already, in

the north of Europe, a number of manufactories have been established, which are conducted upon this plan. But I have observed, in the experiments which I have made on this subject, that a dry heat is less advantageous than one which is moist; and, that in all cases, it is necessary to condense the vapour by opposing its evaporation, in order to give it the necessary activity.

The heat of furnaces has this advantage over that of dunghills, namely, that it produces no exhalation which can alter the colour of the oxyd; an advantage the more valuable, since we know with what facility sulphureous vapours, and hydrogen sulphuretted gas, blacken the oxyds of lead.*

White lead may be formed by another process, which I have practised on a large scale for several years. For this purpose there are dissolved in cold water 100 parts of muriate of soda, in the proportion of four parts of water to one of the salt; the solution marks from 15

* It is above all to the exhalations of sulphuretted hydrogen gas, inseparable from the decomposition of dunghills, that we ought to ascribe the discolouring of white lead, in all those points which are exposed to it.

to 20 degrees: there are mixed and kneaded with it 400 parts of pounded litharge, which forms a soft paste that is left for some time in a state of repose; the mixture is then shaken almost incessantly, and the remainder of the solution of muriate is added in proportion as it thickens, and for want of that some pure water.

The mixture whitens, swells up, and the litharge disappears; at the end of 24 hours, boiling water is poured upon it, to extract the soda; and it is then made to evaporate, in order to obtain the alkali.

The muriate of lead which is formed, assumes a beautiful yellow colour by calcination and melting; it forms a colour very valuable in the arts.

If a little sulphuric acid, very much diluted, is poured upon this muriate, the sulphate which is formed assumes in a moment the colour of a very agreeable white, and becomes of extreme fineness. It may then be washed in water, pounded in order to give it more fineness and consistency, and moulded in pots for the purpose of forming loaves similar to those of ceruse.

This sulphate of lead is very white; it does not become yellow when mixed with the oils; but it has the inconvenience of being too light, and of not being applied well with the brush.

This sulphate may be decomposed with potash and soda; there is thus obtained a white oxyd, pure and very heavy, which differs little from the best white lead of the shops.

There is also known in commerce a white lead, which is called *white of silver*, or *white of Kremnitz*. The analysis of it has proved that it is a very pure carbonate of lead; and I am induced to believe that it is formed of scales selected from the plates, which serve as a cover to the pots; at least, a comparison of it by the eye, the employment and analysis of it give weight to this opinion.

The white oxyd of lead unites in itself those properties which hitherto have made it serve as an excipient for most colours; and it is still almost the only preparation in use for communicating a white colour to the wood and the furniture of our apartments. 1st. It mixes easily with oil; 2d. it preserves its colour when thus united; 3d. it easily spreads under the brush; 4th. it adheres accurately to any sur-

face to which it is applied, and covers it completely and uniformly; and 5th. it undergoes no change, either by the action of air or water.

In consequence of these properties, the white oxyd may be employed, either alone, as a colouring principle, or mixed with other colours, in order to serve as their excipient or basis, and to give them a body.

To the white lead there is almost always added a little lamp-black, to give it that grey tint which is more agreeable to the eye. By varying the proportions, the tints are also varied, and there is formed every kind of grey which may be wished for. Crystallised verdigrise is also sometimes added to white lead, and imparts to it a blueish tint which is very agreeable.

When the works to be painted are in the interior of houses, and therefore sheltered from rain, instead of oil, a solution of gum or glue is sometimes used. This solution is mixed with white lead to a proper degree of consistence, and applied by the brush.

It dries sooner, and does not give out such pernicious exhalations as the other; but it scales off more easily, penetrates and preserves

wood less effectually, does not resist water, &c. Hence it is a bad preservative of furniture, &c.

As ceruse preserves its white colour, when combined with oil, as has been already observed, it may be made the excipient of all colours, to which it communicates a suitable body, and the property of drying speedily.

Ceruse is besides employed for some medicinal purposes, which occasion a great consumption of it. Thus it is used for sprinkling over excoriations, and to dry up superabundant serosity; it absorbs moisture, and moderates the irritability of inflamed parts.

Though the oxyds of lead appear very fixed, they become so volatile by simple handling as to prove deleterious to those who are employed in preparing them.

These unfortunate victims to their trade in a little time become sallow; their voice falters; the flexor muscles are attacked by spasmodic contractions; violent cholics indicate that the stomach is affected, and the scene is at last closed by the patient falling into dropsy, or paralysis.

In the lead-mines, the workmen employed

in melting the mineral seldom reach the age of forty-five.

It appears that oil, which serves as an excipient to white lead, volatilizes a portion of it, and fills the place in which it is employed with a gas extremely subtile, unknown even to this day, and characterized by a peculiar odour. Persons who breathe in this atmosphere are seized with pains, and experience symptoms which have much affinity with those that precede palsy. The danger which attends the inhabiting of apartments newly painted, is well known.

The circumstance which proves, that, in these cases, a portion of the lead is volatilized, is, that if water be left in the place where these emanations are most sensibly felt, its surface becomes covered with a brown oxyd, similar to that which Messrs. Proust and Vauquelin have obtained by surcharging the red oxyd with oxygen, by means of the nitric acid; it would appear, therefore, that the oxygen of the atmosphere is by no means unconnected with this emanation of lead.

These oxyds having become necessary in the arts, it now only remains to put the artist upon

upon his guard against their dangerous exhalations. This may be done, at least in part, 1st. by never grinding the colours but in spacious apartments; 2d. by never grinding them in a dry state; 3d. by covering the face with a mask; and 4th. by the operator placing himself in a current of air, which may carry off the vapours as they rise.

I have observed, that the odour of vinegar speedily corrects the pernicious effect of these exhalations diffused in an apartment. In this case it acts as a solvent, and precipitates the vapours by combining with them.

CHAPTER XX.

SECTION I.

Of the Combinations of Tannin with Gelatine.

HIDES easily become putrid; they are with facility impregnated with water, and destroyed by repeated friction.

All these inconveniences are obviated by tanning, and they then take the name of *leather*.

To tan a hide, is to saturate it with tannin, or the astringent principle of vegetables; and to give it, by that means, a degree of hardness, at the same time that it is rendered incorruptible, and less permeable by water.

We shall not here dwell upon the theories by which the operations and the effect of tanning have been explained; but shall content ourselves with observing that M. Seguin has shewn, that the tannin unites itself with the gelatine which forms almost the whole of the hide, and

that there thence results a new substance possessing properties altogether distinct.

In order that a hide may receive the tan, it is necessary to begin by removing the hair, separating the adhering pieces of fat, stripping it of the epidermis, or scarf-skin, and rendering it supple. These preliminary operations are performed in the following manner:

ARTICLE I.

Of the Washing of Hides.

When the hides which are to be tanned are raw (in which state they are called *green hides,)* they are put to steep in water, in order to clear them of the blood and filth they may have collected in the slaughter-house. They are left to soak in the water for some time; and then *handled,* or trod upon with the feet, the better to cleanse them of all impurities.

If the hides are dry, they are steeped a longer time, sometimes for four days; and care is taken to draw them out once a-day, in order to stretch them on a *wooden-horse,* or *beam.* These two

operations are repeated till the skin becomes *raised,* or well softened.

The neighbourhood and the command of running water are necessary to these first operations. Without that the hides are ill prepared, and the tanning is speedily tainted with all those matters which are thrown off in these preparatory labours.

ARTICLE II.

Of Cleansing or Scowering the Hides.

After the hides have been well softened they next proceed to cleanse or free them from the hair. With this intention several different methods are employed; that which is the oldest, and still most generally followed, consists in the application of lime.

In all tanneries, pits are formed under ground, having their sides lined with stone or brick, in which lime-stone is slacked so as to form *milk of lime.*

These pits are divided into three kinds, according to the greater or less strength of the lime. The hides intended to be scoured are

first put into the weakest of these pits, wherein they are allowed to remain until the hair readily yields to the touch.

If this liquor be not sufficiently active, they are removed to the next in gradation. The time they are soaked is longer or shorter in proportion to the strength of the lime, the temperature of the air, and the nature of the hides; those of sheep only require to remain in the pits a few days. It has been proposed to substitute lime-water in place of the *milk of lime*. But I have observed that though the lime-water acts at first with sufficient strength, its action is not sufficiently permanent, and that in order to succeed in clearing the hides by this means, it is necessary to renew it occasionally; and in this way the hides may be prepared in a few days.

In some tanneries, after they have been kept in the pits for a short time, they pile them up in a heap on the ground, in which state they are suffered to remain during eight days, after which they return them into the same pits from whence they were taken, and this process is repeated till the hair can be easily scraped off.

In many countries they mix a large quantity of ashes with the lime; but the only effect this mixture appears to me to produce is that of rendering the leather less consistent than when lime is solely employed,

Many attribute the bad qualities of leather to the too great use of lime, which has a tendency to burn and render it brittle. Hence in several well conducted tanneries the employment of lime is carefully avoided. Hides may be cleansed by subjecting them to an incipient fermentation, which may be produced in a variety of ways:

1. By souring a mixture of barley flour in warm water, and soaking the hides in it till they are sufficiently swelled and softened to admit of being cleared from the hair. In each tan-house are placed several tubs full of this acid liquor, which is of different strengths, in proportion as it is soured. In those containing the weakest liquor the hides are first soaked, *handled,* and washed; and after two, or at most three of these operations, they are sufficiently prepared to admit of being freed from the hair.

In order to prepare this liquor, 3 myrio-

grammes (equal 66lb. 3oz. and 6 drams avoirdupois,) of barley flour is diffused in boiling water, and put into the caldron whence has been drawn the first water. This mixture is carefully stirred, and boiled so as to froth and bubble up three several times. This farinaceous glue or paste is then transferred into the different tubs, and stirred about with a shovel in different directions, which is supposed to aid the fermentation. The tubs are then covered, and the mass left to ferment. With the view of assisting the fermentative process they employ a leaven, which is prepared as follows: one myriogramme (equal 22lbs. 1oz. 2 drams avoirdupois,) of wheaten flour is mixed with water, and kneaded with a small portion of baker's leaven; sometimes 0,24474 hilogramme (equal 9 oz. avoirdupois) of vinegar are added to it, after which it is closely covered up, and exposed to a gentle heat during two or three days. Before it is used, a portion of the barley flour mixture already mentioned, previous to boiling, is added to the leaven and carefully incorporated with it. Thus prepared it is poured into the different tubs in equal proportions; sometimes it is slightly heated before its intro-

duction. Afterwards 2,93706 hilogrammes, (equal 4lbs. 6oz. 10 drams avoirdupois,) of salt are stirred into each tub, and the mass left to sour for twelve or fifteen days, care being taken to stir it two or three times daily during that period.

This preparation is not merely employed to *raise* and soften the hides, it also serves to cleanse them; if more easily procured, rye flour may be substituted in the place of barley.

The hides prepared with barley flour are termed *Wallachian leather,* while those cleansed with rye flour bears the name of *Transylvanian* or American leather; these last are preferred to the former. The place of this acid mixture is sometimes supplied by the exhausted bark of tan-pits, in which case the hides so prepared are denominated *Spanish leather, Namur leather,* or *Liege leather;* these are all greatly valued in commerce.

To prepare this liquor the exhausted bark is collected from the tan-yard and trodden with the feet in a large basin, pouring in clear water, or water that has stood on the tan, until it be perfectly covered. A hole is then made in the basin, and the water collected as it flows

out, and again poured on the bark, until it becomes acid.

On the coast of Sedan the water is allowed to stand on the bark for six months; and when it has become acid the bark is drawn towards one side of the vessel, so that the water may be conveniently taken up at the other. This liquor is clear, red, and equally acid as good vinegar. More water is then poured three or four times upon the bark, and allowed to remain some hours, after which these waters are mingled with the first liquor. They render this liquor of different degrees of strength by mixing it with a greater or less proportion of water, and use that which is weakest for scowering the hides.

The Calmucks employ sour milk with the same view, and Pseiffer proposes the use of the acid water obtained from the distillation of coal or turf. It indeed appears sufficiently ascertained that all the vegetable acids answer equally well for this purpose.

In some tanneries they cleanse the hides by throwing salt over the one half of the skin, and doubling the other half over it; in proportion as each hide is salted they are laid one above an-

other, and the whole covered with straw or flax; fermentation soon begins, after which they are turned once or twice daily until they are found to be in a proper state for removing the hair. They may be cleansed however, much in the same manner, without the employment of salt, by piling them up on a bed of litter, and covering them with the same material for twenty-four hours. At the end of this period they are turned over, and afterwards examined twice a day in order to ascertain when the hair may be readily removed.

In some tanneries they bury the hides in the dung, while in others they simply expose in a close apartment, termed a *smoke-house*, heated by means of a tan-fire, which gives out smoke without flame. The hides are suspended on long poles placed across these apartments, which are heated to 30 or 35 degrees.

All the methods in which fermentation is employed are termed *heating processes*. But in whatever manner the first part of the operation has been conducted, as soon as it is perceived that the hair is in a fit state to be removed, it is scraped off, on the wooden-horse, by means of a crooked knife, which is not so sharp in any

part of its edge as to injure the hide, or by a whet-stone. This operation is not only intended to remove the hair, but likewise the scarf-skin or epidermis, which is of a very different nature from that of the true skin. It is insoluble in water, and alcohol; is soluble in acids, but not susceptible of combination with tan, so that when left on the hide the tan can only penetrate through the under side, by which means the process of tanning is rendered extremely tedious.

ARTICLE III.

Of the Swelling, or Raising the Hides.

After removing the hair and epidermis, the next object is to free the hides from the adhesion of any part of the muscles, or fat, and to render them soft and pliant. Those which are intended for particular kinds of work, such as calves skins for the upper-leather of shoes, and neats leather for shoulder belts, do not require to be softened or swelled. As soon, therefore, as they are cleansed they are put into one of the tubs containing the sour liquor; and

after being freed from the flesh, &c. are laid into a pit.

The hides intended for the soles of shoes, and other strong leathers, are afterwards *raised* by means of processes which vary in different countries.

When lime is employed, the operation is commenced by putting the cleansed skins into the weakest of the lime-pits, and afterwards passing them successively through the two others. They are kept four months in each of the two weakest pits, and two months in the strongest. During this operation care is taken to withdraw them, and pile them up in a heap, every alternate eight days, as already mentioned, putting them again into the pit after it has been well stirred.

Lime hardens the skin, and in those tanneries where it is used, the hides are put into a ley of pigeon-dung in order to soften them, and this process is termed *graining*. They are daily withdrawn from the ley, and laid up in a heap for half an hour. This operation is usually continued for ten or fifteen days.

Sometimes also the acid compositions, of which we have already spoken, are employed

for raising the hides; and this operation is greatly accelerated by using the acids warm, as well as by the method practised in Britain, of removing them from a weaker liquor into a stronger, until they be properly *raised* or swelled.

Macbride proposed in 1774 and 1778, to employ for this purpose water acidulated with a small portion of sulphuric acid; and I have myself seen hides sufficiently swelled in twenty-four hours by this means, and fit to be scraped.

It is useful to heat this acidulous water to such a degree that the hand may be kept in it without any disagreeable sensation, and to maintain the same degree of heat by having some of it boiling in a caldron to supply the place of that absorbed by the substance of the leather.

It is besides necessary that this liquor be made to penetrate the hides in an equal manner, which is accomplished by washing, dripping, and returning them to the bath several times, after it has been well stirred.

When the hides are thus prepared, the flesh is detached from them on the horse, cleared away, and the skin well suppled.

When the hides have been scraped they are left to drip, then rinced in water, again dripped, and afterwards plunged into the *colouring liquor*, which is prepared by infusing pounded bark into a large tub. This bath has a tendency to stiffen the skin and dispose it to receive the tan; it also imparts to it an agreeable yellow colour.

ARTICLE IV.

Of Tanning the Hides.

The skin being thus prepared, is next subjected to the operation of tanning; and to this purpose vegetable astringents are employed*.

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* Mr. Hatchet has shewn that tannin may be obtained by dissolving either vegetable, mineral, or animal charcoal in nitric acid. With this view he directs 100 grains of charcoal to be digested with one ounce of nitric acid of the specific weight of 1,40, diffused in two ounces of water. The matrass is placed in a sand bath, and a considerable disengagement of nitrous gas at first takes place. At the termination of two days, a second and sometimes a third ounce of acid is added, and the digestion continued during five or six days.

Those vegetables answer best which contain the greatest portion of the astringent principle, now known under the name of *tannin*.

Mr. Davy has demonstrated that caoutchouc or Japan earth, contains more of this principle than any other vegetable with which we are acquainted; but oak bark is the substance most commonly employed in our climates; for it is not only very abundant in Europe, but likewise contains much tannin. Every species of oak, however, does not supply us with bark of the same quality; the white oak is inferior to the green oak which grows in the south, while this in its turn yields in the value of its bark to that procured from the roots of the kermes bearing oak, which is employed in southern climates for tanning strong leathers.

But whatever kind of bark be employed, it is previously ground down to powder. The

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The product of this digestion is of a very astringent taste, and soluble in water and in alcohol; it swells up and becomes carbonized by heat, reddens turn-sole paper, precipitates the greatest number of metallic and earthy salts, in the same manner as gelatine, and acts as the *preserving principle of tanned leather*.

tan-pits are sometimes of a round, and at others of square form, dug out to a considerable depth in the earth, and lined with wood or mason work; their size being in proportion to the extent of the works.

The method of tanning is different in different countries; it may nevertheless be classed under three distinct heads.

Sometimes the tan is employed in a dry state, in which case a layer of bark, which has already been used, half a foot thick, is spread over the bottom of the pit. Over this is placed a stratum of well ground new bark, about an inch in thickness, which is carefully covered by one of the skins; to this succeeds a second layer of tan, and then a skin as before; in this manner the pit is completely filled, after which the whole is covered with half a foot of tan, and well trodden under the feet. This last stratum is termed by the workmen the *hat*.

By this method the operation of tanning is extremely tedious, not being fully perfected till the end of fifteen or eighteen months. This period may however be abridged by pouring a little water into the bottom of the pit by means of a wooden pipe fixed in one of the

corners and reaching to its bottom. In some tanneries the pits have a double wooden bottom, pierced with holes, so that the water may be more equally diffused throughout the mass.

The first bark is allowed to remain for two or three months, at the end of which the skins are taken out and re-introduced with fresh bark as at first, and this process is repeated a third time, at the termination of the next three or four months.

Each time the bark is renewed, they stretch and *handle* the skins with the greatest care.

When the tan is supposed to be nearly exhausted, a strong lixivium of bark is poured into the pit, which produces a very powerful effect; as by this means the trouble of taking out and replacing the hides with fresh bark is spared.

It is more particularly necessary to employ moisture towards the end of the process, as at this period the tan penetrates into the skins with more difficulty, and therefore requires some vehicle to assist its action.

In Britain they dig wells by the side of the

tan-pits, from whence the water is pumped immediately into the pits.

In dressing hides after the Danish fashion, when the preliminary operations are completed, the skins are sewed up like sacks, and filled with a mixture of tan and water. The openings are then carefully closed, and the sacks placed in pits full of tan and water. By this method the tanning is completed in about two months, and the leather thus prepared admits of very great extension.

Rankin and Holle-Waring have satisfactorily proved, that leather may be tanned by a decoction of heath employed tepid.

Macbride recommends an infusion of tan in lime water; but M. Seguin contends that common water is preferable.

The mode of tanning by infusion is extremely expeditious, since by it a few days are only requisite for preparing a bullock's hide, and a few hours for that of sheep. It is however attended with some inconveniences. 1. It requires a large apparatus for lixiviating the bark, and preserving the liquor; as well as an extensive tannery. 2. The leather being im-

pregnated with so great a quantity of water, remains spongy a long time, and wrinkles on drying. 3. It appears to me extremely difficult so to arrange the hides in a copper, that they may be kept apart from each other and from the sides of the copper, as without particular attention be paid to this arrangement, the tanning will always be unequal.

I have besides observed that weak infusions of tan produce very little effect, and consequently it must prove a very difficult process to bring the lixivium to a proper degree of concentration.

The best method is therefore to render the tan slightly humid; so that the astringent principle is constantly presented to the hide in a state of solution. The action of the exhausted bark may towards the end of the process be assisted by pouring into the pit an infusion of tan.

By this process from three to four months are only required for tanning completely a bullock's hide.

The human skin, and that of the hog, are tanned with the greatest difficulty, since it has been found by experience to be extremely dif-

ficult to detach the portions of flesh which adheres to them.

According to calculation from five to six pounds of tan is required to each pound of strong leather; and one hundred weight of hides yields from 52 to 56 pounds of leather.

CHAPTER XXI.

Of the Combinations of Alkalies.

SECTION I.

Of the Combinations of Alkalies with Oils.

THE combination of an oil with an alkali uniformly produces a compound soluble in water, and in which the characteristic properties of oils and alkalies are destroyed or changed.

These combinations are termed *soaps*; but as those of soda or potash are only employed in the arts, it is those alone that we shall at present particularly consider.

It is probable that ages must have elapsed before mankind arrived at a knowledge of the combination of oil and alkali which we term soap.

Saponaceous plants, argils, marles, and mag-

nesia, appear all to have been employed in cleansing linen long anterior to the discovery of soap.

We even see that some animal matters were employed with advantage for the same purpose, such as the bile and excrements of hogs, which are still very generally used in Britain.

It is equally certain that the use of ash leys preceded the discovery of soap.

But the capability of combining oil with alkali so as to form a solid compound, soluble in water, and which can dissolve spots of grease, without changing the colour of the stuffs on which they are found, is a discovery of inestimable value in the arts.

This discovery successively improved, constitutes what is now termed *the art of soap-making*.

ARTICLE I.

Of the Substances employed in the Manufacture of Soap.

Oils and every kind of grease, are susceptible of combination with the alkalies, so as to

form soaps; but they do not all furnish soap of an equally good quality.

It is of importance then to ascertain the various matters that may be employed for this purpose, and shortly to point out the differences between them with the view of directing the choice of the artist.

§ I.

Of Oils and Grease.

Olive oil is generally employed in the preparation of soap. It combines perfectly with the soda; the soap thus produced is very white, uniform, of a proper consistence, and exhales an odour which is peculiar to this kind of soap.

But every kind of olive oil is not equally proper for saponification; three kinds are known in commerce; *sweet* or *virgin oil, common* or *dyer's oil,* and *expressed oil.*

The first is that which flows upon the pressure of the olive, the second requires a stronger degree of pressure assisted by heat, and the

third is produced by great pressure exerted on the refuse of the olives, in order to extract every remaining particle of oil, and which is always mingled with a considerable quantity of mucilage, and ligneous bodies.

The first is pure, and almost wholly free from any viscous principle.

The second is mixed with a considerable portion of mucous matter which forms with the oil a species of emulsion.

The third contains little oil, and a great portion of the mucous and fibrous principle.

The *sweet oil* burns with facility, and without leaving much charcoal.

The *dyer's oil* does not burn so readily, and yields a considerable quantity of charcoal.

The *expressed* or *coarse oil* burns with great difficulty.

The manner in which these oils unite with alkalies is very different.

The purest oil does not readily incorporate with them. When an alkaline lixivium is poured on such oil, the mixture immediately assumes a milky hue, and appears homogeneous; but the oil quickly separates, and swims on the surface of the liquor, where it forms a

stratum, in which are observable separately some drops of oil, and a saponaceous *magma* in which the oil predominates. The lixivium which remains underneath appears only like a liquor slightly milky, and of an opal colour.

Dyer's oil enters into a much more intimate union with alkaline lixivia. It is readily miscible with them, and does not separate; so that it may be even inspissated by heat without destroying the combination.

The third species of oil is seldom employed singly; for though we may succeed in forming a durable combination, yet the soap produced is of a very inferior quality.

In order to ascertain whether the oil be of a good quality, we ought to have at hand a lixivium prepared without heat, and indicating from one to two degrees of concentration. Having introduced into a phial a few drops of the oil the quality of which we wish to prove, we pour upon it some lixivium. Immediately upon the mixture becoming milky, we transfer it repeatedly from one phial into another, and allow it afterwards to remain at rest in the phial.

If, after the lapse of a few hours, the combi-

nation remains uniformly white, and no particles of oil appear on its surface, we may rest satisfied that the oil is of a good quality; and, if the contrary, that it is bad.

Pure oils require stronger lixivia than those of a coarser kind.

Common oil is only employed in soap manufactures, not only because it bears a less price, but because it *saponifies* better. Fine oil is reserved for the use of our kitchens and tables.

It is particularly from Italy, and chiefly from Genoa, that we procure the best oil for our soap manufactures.

Some oil is also imported from Barbary, which, conjointly with Genoa, supports the immense soap works established at Marseilles.

Next to olive oil, that of sweet almonds yields the most *consistent* soap. But as this oil bears a high price, it is only employed in the composition of *medicinal soap.*

Rape oil forms a soap neither so consistent nor so white as the former.

Hemp-seed oil produces a porous green coloured soap, reducible to a paste by a small portion of water.

The soaps prepared with the oils procured

from beech-mast, and clove July-flowers, are of a clammy, glutinous consistence, and gene- of a greyish colour.

Nut oil forms a soap not proper for the hands; it is of a yellowish white colour, of a moderate degree of consistence, unctuous, gluey, and continues so on exposure to the air.

The soap of which lint-seed oil forms a constituent part, is at first white, but changes to yellow in a short time, on exposure to the air. It possesses a strong odour, is unctuous, clammy, glutinous, does not dry in the air, and softens with a very small quantity of water.

From what has been said we may conclude, that the soaps prepared with desiccative oils are of a very indifferent quality, that they remain always glutinous, and readily change their colour on exposure to the atmosphere.

All the oils of which we have spoken, are either *oleaginous* or *fixed*. The volatile oils are not however less susceptible of entering into combinations with the alkalies; but as these soaps are not employed in the arts, we shall not notice them in this article.

Many animal substances are capable of com-

bining with alkalies, and furnish us with valuable materials for the formation of soap.

Suet forms, with soda, a white soap of an excellent quality; excepting only that it always retains a slight odour of grease, which it imparts to linen.

Strong lixivia are necessary to the saponification of suet, or its conversion into soap.

This soap requires much water to soften it, and destroy its consistency.

At Arsamas, a Russian city, and the capital of the district of that name, they prepare great quantities of soap with suet and the ley of ashes; the caldrons employed by them are made of hammered iron. The product of each boiling amounts to eighty quintals of soap.

The soap made with axunge is of a fine white colour, of a firm consistence, and exhales no disagreeable odours.

Butter may also be converted into soap by combining it with soda. The soap thus produced is white and solid.

Pelletier prepared a white, solid soap, without odour, by combining the oil drawn from the grease of horses with soda.

Bullion obtained an excellent soap, by combining, without the aid of heat, 25 pounds of the last mentioned oil, and an equal quantity of that of clove July-flowers, with 25 pounds of concentrated soap leys.

Fish, and train oils, produce soaps of a dirty grey colour, of a firm consistence, and retaining the smell peculiar to these oils.

Oleaginous and fatty matters may be classed in the following order, as to their susceptibility of saponification.

1. Olive oil, and that of sweet almonds.
2. Suet, axunge, butter, and the oil extracted from the fat of horses.
3. Oils drawn from rape-seed.
4. Oils procured from beech-mast, and clove July-flowers.
5. Fish oil of different kinds.
6. Hemp-seed, nut, and lint-seed oils.

I long since proposed the employment of old wool, and the shreds and shearings of woollen cloth for the formation of soap. Caustic alkaline lixivia readily dissolve these animal substances, and may be saturated with them, thus producing a saponaceous greenish paste, which might be successfully employed in the arts, for

the fulling of cloth, and other purposes. This process is already well known and pursued in several manufactures, wherein they form this soap with old wool, and the caustic ley of common ashes. It is, however, a matter of regret, that its preparation is yet far from being general, as it might be applied to a great variety of purposes, and as its composition is equally easy and economical.

§ II.

Of Alkalies.

The three species of alkalies: soda, potash, and ammonia, may all be employed in the formation of soap.

Soda and potash are the only alkalies employed in preparing the soaps of commerce. Ammonia is only used in forming some saponaceous composition for medicinal purposes.

Soda forms firm and consistent soaps.

Potash forms soft soaps, which attract humidity from the atmosphere.

This difference proceeds from the nature of the alkalies, the former of which effloresces in

the air, while the latter, on exposure to it, runs per deliquium.

It rests not therefore with the artist to employ the soda or potash indiscriminately; his choice must be regulated by the kind of soap which he wishes to procure.

All marine vegetables yield soda by incineration, but they do not furnish it in the same quantity, nor of the same quality.

The alkali in the soda is always found mixed with marine salt and earthy matters; the best is that which contains the greatest portion of the alkaline principle.

The only kinds of soda employed in the manufacture of soap, are the *barilla,* or *soda of Alicant,* the *salicornia,* or soda of *Narbonne, Sicilian ashes,* and *natron.*

The sodas held in the highest estimation are those of Alicant, of which three kinds are to be found in the shops: 1. The *mild soda,* or *mild barilla,* which is of the best quality; 2. The *soda properly so called,* or the *mixed barilla.* This is hard, of a smooth fracture, of a greyish black colour, and difficultly soluble in water; 3. *Counterfeit soda,* which is of the worst quality.

The sodas of Carthagena possess nearly the same qualities as the *mixed barilla* of Alicant.

Sicilian ashes, and those from the Levant, are inferior in quality to the sodas of Alicant, though when these last cannot be obtained, they are frequently made to supply their place.

Natron is likewise very much employed; the low price at which it is sold, during peace, operates to induce manufacturers to use it, though it contains very little pure alkali.

Potash, properly so called, is rarely employed in this state for the formation of soap. Instead of it, the ley of ashes, rendered caustic by lime, is now very generally substituted.

ARTICLE III.

Of Solid Soaps, or Soaps of Soda.

The white and solid soap of commerce is composed of olive oil and soda.

The preparation of the leys, and the boiling of the soap constitute the principal operations in such manufactures.

SECTION I.

Of the Preparation of the Leys.

The alkalies, such as they are found in commerce, cannot be employed in the manufacture of soap.

They must previously be deprived of the carbonic acid, the saline and earthy matters which they contain. This process is conducted in the following manner:

Into a vessel, about eight feet square, and one foot deep, is introduced quick-lime, in the proportion of one-fifth to the weight of the oil intended to be converted into soap. Water is slightly sprinkled over this quick-lime; which then grows hot, cracks, smokes, and falls down into powder, after which the soda, previously pounded, must be carefully mixed with it by means of a shovel. In order to favour the operation, a little water is occasionally added.

As soon as the mixture is accomplished, it is transferred into tubs, termed bugadières, in the manufactures at Marseilles.

In small establishments their vessels are made

of white wood, but in those which are on a larger scale, they are composed of stone, lined with bricks formed on the spot, and sunk into a mortar made with puzzolana or similar earths.

Frequently these vessels are constructed of bricks laid flat, and cemented by a mortar of the same kind.

These vessels are usually about five feet square, by four and one-half feet in depth. They are perforated, at the lower part of the side next the work-house, with two holes, or openings, which are closed by a stop-cock, or pegs of wood.

Under each of these vessels are placed two reservoirs constructed with the same care, and intended for the reception and preservation of the leys. At Marseilles they term these vessels *récibidous*.

At the bottom of these vessels are placed pieces of broken tiles to facilitate the efflux of the ley.

When the mixture of lime and soda has been transferred into the tub, there is poured on it a quantity of water sufficient to cover it, to the height of one foot and a half.

After leaving the water in this state for several hours, it is drawn off, by means of a spigot, into one of the reservoirs placed beneath.

This ley marks from 15 to 20 degrees of concentration, and is called the *first ley*.

After the ley has ceased to run, and the spigot been shut, water is poured into the tub as before; and, at the end of a few hours, drawn off into the second reservoir. This is termed the *second ley*, and indicates between 10 and 12 degrees of concentration.

A third ley is extracted with the same care; it only marks from 4 to 6 degrees.

The soda is still further exhausted, by pouring on it a fourth water, and even a fifth, if it appear necessary.

The last leys are employed, as common water, for the lixiviation of a fresh soda.

When the soda is completely exhausted, the tubs are emptied, and the residuum thrown aside as useless, or employed as manure on wet land.

To facilitate the labour of the manufacturer, water is conducted by pipes into each vessel, or tub. Furrows or trenches are also formed in the front of these vessels, by means of

which the ley may be more conveniently circulated.

As sodas are not all equal in point of quality, the ley produced is often extremely different. The overseer forms his judgment as to its degree of concentration, by the water-poise, or by means of a fresh egg, which sinks in the liquor, in proportion to the weakness of the lixivium; adding, according to circumstances, a portion of a stronger or weaker ley, to bring it to the proper standard.

Leys are also powerfully influenced by the seasons; thus, in winter, they are weaker, unless attention be given either to employ sodas of the best quality, or in a greater quantity.

The proportions of soda and lime employed are different, in different countries, and in different establishments; in some they employ equal parts, while in others they use only one-sixth of quick-lime. This difference appears to depend on the lime, and, more frequently, on the nature of the soda. In general, old sodas and natrons require the most lime. Lime, in a state of efflorescence, possesses not the same power as that which is recent; and as this is not always at hand, we preserve it in

proper repositories sheltered from the contact of air and moisture, in order to obviate all change.

It is seldom that the manufacturers of soap confine themselves to one kind of soda in the formation of the lixivium; they, for the most part, employ a mixture, in different proportions, of natron, Alicant soda, Sicilian ashes, the salicornia of Narbonne, &c.

SECTION II.

Of the Boiling of Hard Soap.

The art of combining oil with caustic soda, and of reducing this combination to a suitable degree of consistence, is the most difficult, and the most important operation of soap making.

This combination is performed in a caldron, and by the aid of heat.

The caldron used in soap manufactures is of a peculiar construction; the lower part of it is of copper, while its sides are constructed of mason, or brick-work.

Much skill and dexterity are requisite in erecting such furnaces, for it must be obvious, that if the junctures be not well closed, the

matter would escape. On the other hand, the expence attendant on their erection is so great, and the suspension of the labour so inconvenient, that nothing should be neglected to give to them the greatest possible degree of solidity.

If the operations be performed in caldrons entirely metallic, instead of those above mentioned, not only will the soap be less white, but the management of the process be rendered extremely difficult, inasmuch as the metal, being a more ready conductor of heat than stone, occasions the saponaceous matter to boil over, and frequently burns it.

These furnaces have this further peculiarity, that the grate is placed behind the bottom of the caldron itself; while the chimney is immediately above the door of the fire-place, so that the flame and heat are reverberated towards the opening before gaining the chimney. An idea of its construction may be attained by examining *fig.* 1, *pl.* 6, *vol.* 1.

Soap-boilers' caldrons vary in their capacities in different manufactures; in general, however, they furnish from 50 to 200 quintals of soap per boiling.

The manner of boiling the soap likewise

varies in different establishments; in some they employ weak lixivia, and in others that which is very strong. We shall here, as succinctly as possible, describe these two methods.

The lixivia being prepared, the next step is to put into the caldron all the oil intended to be employed. It is not, however, possible previously to ascertain the exact quantities of oil and soda, as these proportions vary according to the nature of the soda and oil, and can therefore only be known from experience.

In general, six parts of olive oil are used, with five of soda. In some soap-houses the oil is boiled previous to the addition of the ley; but when the oil is extremely thick, and contains many impurities, it is mixed with a strong lixivium, and then boiled: the clear and transparent oil quickly rises and ascends to the surface, while the impurities are precipitated. The fire is then stopped, and the workman removes the supernatant oil, from the gross matters, which have subsided. After cleaning the caldron, and returning into it the oil which had been taken off, he rekindles the fire and proceeds to the boiling.

He pours some buckets of the weakest ley

on the oil, and digests the whole with a gentle heat, which is carefully kept up, till the soap be completely made. The combination is facilitated by incessantly agitating the mixture with a long wooden spatula. There is added, gradually, more of the same lixivium; and, when it is exhausted, the second is employed.

The oil gradually combines, the matter thickens, and becomes white; more of the first ley must then be added, after which the paste soon becomes more consistent, and separates imperceptibly from the aqueous liquor. Messrs. Pelletier, Darcet, and Lelièvre advise us, at this moment, to throw into the caldron a few pounds of sea salt, in order to produce a more complete separation; the paste then assumes a grained form, having some resemblance to spoiled cream; the ebullition is maintained, during two hours, after which the fire is withdrawn, and the agitation discontinued.

When a few hours have elapsed, the liquor, which remains at the bottom of the caldron, is drawn off by means of a pipe, communicating with its inferior part; the fire is rekindled; the soap is dissolved by the aid of a little water poured into the caldron; the mixture is agi-

tated, and when it is completely liquefied, and in a boiling state, the remainder of the first ley is gradually added to it.

We ascertain that the soap has attained a due degree of consistence: 1. by allowing a small portion of it to fall and coagulate on a slate; 2. if, on shaking a spatula, dipped into the paste, briskly in the air, the soap is detached in the form of ribbons, without adhering to the wood; 3. by the particular odour of soap; by handling it between the fingers.

Although the method of *graining* the soap, and separating the aqueous part be far from common, yet it has been successfully employed in many establishments since it was made known. The process may unquestionably be conducted without the aid of salt; but as it frequently happens that the process misgives toward the conclusion, and thereby embarrasses even a skilful manufacturer, it may not be improper to point out the means of remedying it.

In some manufactures the strongest lixivium is employed at the commencement of the ebullition; by which method the paste becomes quickly thickened to a considerable degree, and requires to be managed by persons skilled in

such operations. It is judged necessary to pour in fresh ley, when the paste sinks down, and remains at rest. They continue to employ the strong ley till it be nearly exhausted. Then the boiling subsides, that is, it sinks down, and appears as if stationary; it boils in this manner during three or four hours; after which it is moistened by pouring into it the second lixivium, while care is at the same time taken progressively to augment the heat. It very rarely happens, when the strongest lixivium has been used at the beginning, that the third ley is necessary. This is only employed when the paste does not boil, because then the object is to dilute it.

As soon as the boiling is finished, the fire is withdrawn; the lixivium is then drawn off, after which the paste is left to cool, and taken up, before it be fully coagulated, by means of copper or wooden buckets, to be transferred into moulds, into the bottoms of which, a portion of pulverized lime has been previously introduced, to prevent the soap adhering to them.*

* Those vessels are termed moulds into which the saponaceous paste is poured from the caldron. They are usually

At the end of two or three days, when the soap becomes sufficiently hard, they remove it from the moulds, and divide it into wedges of different sizes, by means of a brass wire.

They place these wedges on a floor, edgewise, where they are allowed to remain till they become perfectly firm and dry.

The fair trader lays his account in procuring five pounds of soap from three pounds of oil.

The soap is not marketable, till it ceases to receive any impression from the fingers.

It must not be supposed that the lixivium employed at the commencement of the process should be constantly continued. The great art of soap-making consists in knowing to determine, from the appearance of the paste, and other circumstances, what kind of lixivium should be employed during each step of

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frames of wood made of several planks kept together by adjusting screws. Some of these moulds can contain two thousand weight of soap at once. They fold down in the front that the soap may be more easily withdrawn. Their construction is such, that in general the lixivium which flows from them can be collected in a reservoir, formed for the purpose.

the operation. The overseers regulate their conduct in this respect by observation and experience The form and size of the bubbles, the colour of the paste, the volume of that which is thrown out on the edges of the vessel, the consistence of the matter, and its disposition to swell, as well as the appearance of the steam, all furnish them with marks by which they regulate their conduct.

It sometimes occurs that the paste, though apparently very firm, yet when set in the cold air to concrete, throws out much water, and is resolved into small grains possessing little consistence. In this case it is evident that the ley is in excess, and must be dissipated by heat, or precipitated by means of marine salt.

Frequently also the paste becomes *greasy*, and the oil appears to separate from the soda. As this in general proceeds from the paste not being imbued with sufficient water to keep it in combination, it is necessary to add to it a portion of water, or very weak lixivium to remedy this defect.

In manufactures of white soap, it is usual to *vein* some portions of it, of a red and blue colour, in order to form what is termed *marbled*

soap. The oxyds of iron are employed for this purpose; but it is not till after two days boiling that they begin the process of variegation. With this view, one hundred and fortieth part of the sulphate of iron, relatively to the oil intended to be formed into soap, is diluted, and decomposed with a weak lixivium. This solution is then poured into the caldron, which is kept in a state of ebullition till the paste becomes black; after which the fire is extinguished, and the lixivium which remains unincorporated drawn off. When this is done they rekindle the fire, and supply the paste with ley during twenty-four hours; after which the fire being put out, the matter is left to settle, and the lixivium drawn off as before.

This process is repeated for nine or ten days, at the end of which the fire is removed, and the lixivium evacuated. As soon as the mass has settled, 5 or 6 kilogrammes, (about 12 lbs. avoirdupois) of Spanish brown, diluted with water, are added to it.

When this is done, two workmen stationed on boards set over the caldron, and furnished with long poles, to the extremity of which is at-

tached a board about ten inches square, raise up the paste and agitate it in different directions, while others pour lixivium in at intervals, till the paste be rendered fluid. After this operation the soap is removed into the moulds.

Marbled soap is harder than that which is white, and is preferred to it for washing. This hardness, in my opinion, does not merely proceed from the parts of the paste being brought into closer contact, but from a portion of oxygen abandoning the oxyd to combine with the iron. What tends to strengthen this hypothesis is, 1. That the marbled soap never acquires its genuine quality, until by ebullition, the colour of the oxyd has been reduced to a blackish tint. 2. Because white soap, though very hard, never assumes the same character as the marbled.

At all times has the soap manufactured at Marseilles, stood deservedly high in the public estimation; cupidity has, it is true, sometimes operated on certain individuals to impose this article on customers, in an adulterated state; but the manufacturers, who are necessarily interested in supporting its character, have never

failed on such occasions to stigmatize them as they deserve.

The adulterations most commonly practised, are the following:

When the soap is made, they add to it much water, which communicates whiteness to it. Frequently they incorporate it with pulverized lime, calcined gypsum, or white argil.

The former of these frauds is readily discovered by the waste of the soap when left exposed to the air for some time.

The second can only be detected by forming a solution of soap in much water, as then the earthy matters are precipitated.

Its adulteration, by means of water, is practised with less advantage by the manufacturer than the dealers in retail.

To discover this fraud, nothing more is necessary than to expose the sophisticated soap for a few days to the air, by which it is flattened, becomes tough, and acquires a yellow hue.

ARTICLE II.

Of Soaps formed without Heat.

It has always been a desideratum with manufacturers to form soap without the aid of heat. Even at the present day this object is still regarded as worthy of attention. But though we have succeeded, by various processes, in manufacturing soaps of an excellent quality in this way, yet the method usually employed has not hitherto been abandoned, which clearly proves that no great advantage has resulted from preparing them without heat.

When we mix together a strong lixivium with oil well adapted for saponification, or the formation of soap, it is sufficient to leave the mixture at rest, that it may assume a considerable degree of consistence. The soap coagulates, and remains supernatant on a clear liquor, which separates from it in great abundance.

It has been observed, that in order to com-

bine an oil with a ley, without the aid of heat, it is necessary to churn and agitate the mixture briskly. For this purpose, a kind of churn-staff, similar to that used in making butter, is employed. The oil is mixed in the proportion of two parts with one of the lixivium, at 8 degrees of concentration. The mixture is agitated for a quarter of an hour, and after adding to it one pint and a half of lixivium at 18 degrees, it is again agitated for one hour and upwards. Finally, after pouring upon the mass a like quantity of lixivium at 18 degrees, it is agitated until the paste becomes of a proper consistence. This paste is left to repose for two or three hours, before removing it from the vessel. After softening it with a spatula, it is run into the moulds.

In the course of a few days, the soap becomes sufficiently hard to be taken out of the moulds.

Rape seed, and some other oils, require a lixivium at 20 degrees of concentration, and two months are requisite to dry the soaps thus produced.

Apothecaries and druggists prepare a medicinal soap by combining two parts of oil of

almonds and one part of soap leys, so concentrated, that a phial which is capable of holding 8 ounces of water, may contain 11 of ley. The soap thus prepared acquires consistency within a few days. It retains sometimes a caustic taste for a short period, but this may be obviated by combining with it a fresh portion of oil, or by preparing it with greater care at first.

The grease collected in kitchens, may be employed in the composition of soaps, prepared without the aid of heat. With this view, to 6 pints of lixivium at 10 degrees, must be gradually added, constantly shaking the mixture, 3 lbs. of grease, melted in a copper basin. The basin is kept on warm ashes for one hour, while at the same time the agitation is continued. It is then taken from the ashes, and agitated again for half an hour, till the mixture thickens. The saponaceous paste thus prepared, is run into an earthen pan, in which it is left till the following day, when being stirred, it is poured into moulds.

Within three or four days it is taken out of the moulds, and set to dry, till it acquires a suitable degree of hardness.

ARTICLE IV.

Of Soft Soaps.

Soft soap is composed of potash and oil. This soap is very useful in scouring and cleansing stuffs from greasy matters with which they happen to be soiled.

The greatest manufactures of soft soap are established in Flanders, Picardy, and Holland. The fish oil used by the Dutch, which imparts a disagreeable odour to the soap, has not a little contributed to bring their manufacture of this kind of soap into discredit.

The use of this oil is prohibited by law in Flanders and in Picardy.

The oils employed in these countries, for similar purposes, are principally those drawn from flax, hemp, and rape seed. These are distinguished by the appellation of *warm and cold oils*. Those which the Flemings denominate *warm oils*, the inhabitants of Picardy call *yellow oils*, and restrict the term *green oil* to *cold oil*.

The warm oils bear a higher price than those

called cold ; and on this account they are frequently mixed.

The kinds of potash employed for the formation of soap, are procured from the North, or from Alsace.

The caldrons are composed of plates of hammered iron, fastened together with rivets.

After introducing into the caldron the half of the oil intended for one coction, the fire is kindled, and when the oil begins to grow hot, we add to it a portion of the lixivium ; what remains of the oil and the lixivium must afterwards be gradually poured in during the ebullition.

If too much of the lixivium be employed at the commencement, no combination takes place ; if the lixivium be too strong, the mixture separates into clots, and if it be too weak, the union is incomplete.

The quantity of the ley employed in one coction, ought to be in the proportion of four parts to three of the oil. Two hundred parts of oil, and one hundred and twenty-five of potash, yield three hundred and twenty-five of soap.

When the union is fully accomplished, and

the liquor rendered transparent, nothing remains but to employ the necessary degree of coction.

The soap-boilers judge of the degree of coction by the consistence, by the colour, and from the time which the soap takes to coagulate.

In order to make the froth subside, and render the mass fit for barrelling, one ton of soap is emptied into the caldron.

The soap held in the greatest request is of a brown colour inclining to black.

The manufacturers in Flanders dye the soap by throwing into the caldron, half an hour before the termination of the boiling or coction, a composition of one pound of the sulphate of iron, half a pound of galls, and an equal quantity of red wood, and boiling it with the lixivium.

When the soap is prepared with a great portion of *warm* or *yellow oil,* a green colour may be imparted to it by pouring into the ley a solution of indigo. This soap is reckoned of the best quality.

This soap remains always in the state of a

soft paste, on which account it is placed in casks as expeditiously as possible.

ARTICLE V.

Of Domestic Soaps.

The only advantage in rendering soap of a hard and solid form is to facilitate its carriage, and to adapt it to certain manipulations; but for a great variety of purposes, it is reduced into a liquid state, to render its employment more convenient.

For domestic purposes, the operation of coction in the preparation of soap, might, in my opinion, be superseded, by the formation of a saponaceous liquor well adapted for the purposes of cleansing and whitening of stuffs and linen.

The preparation and employment of these saponaceous liquids have long engaged my attention, and as my experiments on this have been attended with the happiest success, I

shall here enter into some details respecting them

1. We may employ either the potash sold in the shops, or a strong ley of common ashes.

In the first case we pour water on the potash, and allow it to dissolve, till the solution marks 2 degrees of concentration. We then decant this solution, and pour it on a portion of oil contained in a vessel. The mixture instantly becomes of a white colour, and forms a milky liquor. In general, we ought to employ a small quantity of oil, and at most, not more than the proportion of one-fortieth part to the bulk of the ley.

In the second case, we mix a portion of quicklime with the ashes we mean to employ, and then lixiviate them, in the usual manner. This lixivium is used, like the solution of potash, after having been brought to the proper degree of concentration.

This lixivium should always be prepared immediately before being used; and for this purpose recent ashes answer better than those that have been long kept. The *coarser oils*, termed *dyer's oils*, are also preferable to the purer kinds in the composition of this mixture.

When they exhale a disagreeable odour it is communicated to the linen; but this fault may easily be corrected, by rincing it through a pure lixivium.

When the liquor is too thick, it ought to be diluted with a weak lixivium; it should likewise be agitated, and beaten up to a froth, before being employed.

When soda is used instead of potash, it must first be grossly pounded, and then put into a vessel and covered with water, by which means we obtain a solution marking 2 degrees of concentration.

The oil being put into a proper vessel, from forty to forty-five parts of the solution of soda is poured on it, when the mixture immediately assumes a milky appearance, which it ever afterwards retains, if the oil and soda be of a good quality.

The Alicant soda is the best with which we are acquainted, and the addition of lime will be found unnecessary, except the soda be old, or in a state of efflorescence.

Several lixivia may be thus formed, by pouring fresh water on the undissolved soda.

Independently of these very simple processes, soaps may be formed with rancid butter, and

other oily or greasy substances, rejected in the kitchen.

I have also succeeded in procuring a soap from wool; which, at the same time that it is extremely economic, possesses very excellent qualities. To prepare this soap, it is sufficient to saturate a boiling lixivium, with the wool rejected in our manufactures.

This soap answers extremely well for scowering or cleansing stuffs.

The British prepare a very economic soap from the remains of the fish which is employed in the formation of glue, and of those that are salted for the market.

Cases may occur in which, though possessing potash, marine salt, and oil, it is impossible to find a supply of soda proper for saponification; yet, even under such circumstances, hard or solid soap may be prepared by decomposing the soap of potash by the marine salt. Thus, for example, if we combine 3 lbs. of oil with a sufficient quantity of potash to form a soft soap, nothing more is requisite, but gradually to add, towards the end of the process, 6 lbs. of marine salt. The saponification is begun with the potash, and completed by the salt.

ARTICLE VI.

Of the Uses of Soap.

The first and most important use of soap is, that of scowering or cleansing stuffs, because it possesses the property of uniting with the oil or grease, by which they are soiled, and rendering them soluble in water, without dissolving or changing the texture of woolen, silk, or cotton fabrics of any kind whatever.

The manner of scowering or washing varies according to the nature of the cloth and the consistence of the soap; when the soap is hard, hand washing is usually employed; or in other words, the soap is rubbed upon the cloth itself, with the view of forming a direct combination between the oil or grease contained in it, and the soap; the matters thus combined are then washed out by the aid of water.

The soap is frequently dissolved in water; and this saponaceous liquor is used to impregnate the cloth, and extract from it by repeated friction, and the employment of water, all the greasy matters with which it is imbued.

Woolen cloth, blankets, flannels, and indeed all animal substances, are most effectually cleansed by soft soaps, or soaps of potash.

Some waters are not favourable to the solution of soap; those impregnated with earthy salts decompose it.

Soda soap forms the basis of wash-balls. With this view it is melted, and then mixed with fine starch, which is the only article besides the soap used in the preparation of the common kinds.

The usual proportions are three parts of starch to five of soap; the soap being cut into finger lengths is melted in a caldron, and two-thirds of starch thrown in, care being taken to stir it frequently; it is next poured on a board, or smooth table, and the remaining third of the starch kneaded into it with the hand until they be sufficiently incorporated; after which the paste is made up into the shape that may be desired.

Another kind of wash-balls are prepared by dissolving white soap in alcohol. To this purpose alcohol is digested upon soap previously cut into finger lengths; and at the end of twenty-four hours this mixture or paste is tri-

turated in a mortar, with aromatics reduced to powder, or with a small quantity of some aromatic oil, such as that of jasmine, tuberose, lemon, citron, and orange. When the paste is become sufficiently consistent, it is formed into balls which exhale an agreeable perfume.

Sometimes the aromatics are incorporated with mucilage of gum tragacanth, and whites of eggs.

It is customary, in some manufactures, to prepare an aromatic dye, by infusing different aromatic substances in alcohol, and afterwards kneading a portion of it with the soap, to which it imparts a strong perfume.

Different saponaceous essences are prepared by dissolving aromatic soaps in double their weight of ardent spirits.

CHAPTER XXII.

Of the Combinations of Alcohol.

The solution of resins in alcohol and in oils, form varnishes, with which wood and metals are covered, to preserve them from the immediate action of air and water.

In order that varnish may unite all the most desirable properties, it is necessary,

1. That it should prevent the immediate contact of air and water with the varnished body.
2. That it do not scale off.
3. That it be sufficiently transparent not to obscure nor alter the colours of the bodies it is intended to preserve.
4. That it resists the action of air and water.
5. That it be susceptible of receiving a fine polish.

Though, in some cases, varnishes should possess all these different properties, yet there

are others in which several of them are wholly useless. Transparency, for example, is not absolutely essential to these compositions, except when we wish to preserve, without alteration or change, a beautiful picture, the colour of wood, or the polish of metal. But in every case varnishes ought to resist the action of air and water, and apply uniformly, without cracks or fissures, to the body or substance covered with them; at the same time that they are susceptible of being well polished.

From what has been said, it is evident, that resins are perfectly suited to form the basis of varnishes, and that it is sufficient to dissolve them in alcohol or in drying oils, to impart to them all the properties that are essential to a good varnish.

Varnishes, then, vary not only according to the colour and consistence of the resins employed, but also according to the nature of the solvent. They are distinguished into *drying varnishes*, *essential varnishes*, and *fat varnishes*, according as alcohol, spirits of turpentine, or fixed oils, are employed in their composition.

SECTION I.

Of the Combinations of Alcohol with Resins.

Alcohol may be regarded as the universal solvent of resins; and the varnishes which result from this solution are extremely brilliant, and dry very quickly; but they possess the inconvenience of being brittle, and cracking unless there is added to the composition a portion of turpentine, or some other substance to render them gluey.

In the preparation of drying varnish, the resin is reduced to powder, and mixed with pulverized white glass; these materials being put into a matrass, the necessary quantity of alcohol is poured over them, after which the matrass is placed in a copper filled with hot water, which is kept in a boiling state for one or two hours. During this period the mixture is constantly stirred with a wooden rod; and when the solution appears to be completed, the turpentine, previously liquefied by exposing the bottle containing it to the steams of

hot water, is added to it. The matrass is then left for half an hour in the water, after which it is withdrawn, and the mixture agitated until it has become partly cold. On the following day it is poured off and filtered through cotton.

The white glass, recommended by M. Tingry, proves extremely useful in this operation, by dividing the resins, preventing their adherence to the bottom of the vessel, and retaining the extraneous matters with which they are frequently mingled.

M. Tingry gives the following receipts for the preparation of drying varnishes, which appear to be extremely well calculated to answer the different purposes for which they are intended.

	oz.
1st. Pure mastic .	6
Sandarach . .	3
Pulverized glass .	4
Venice turpentine .	3
Alcohol . .	32

This varnish is extremely brilliant, without possessing much consistence. It is chiefly

used for varnishing pasteboard, boxes, pen-cases, &c.

	oz.
2d. Liquefied copal * .	3
Sandarach . .	6
Pure mastic . .	3
Pulverized glass .	4
Pure turpentine	$2\frac{1}{2}$
Alcohol . . .	32

The present varnish, which is more consistent and equally brilliant as the former, is mostly employed for varnishing such articles as are exposed to great friction; such as carriages, different kinds of cases, window and door frames, metals, &c.

By augmenting the portion of the sandarach and turpentine, a stronger body is given to the varnish, while it is at the same time rendered much more pliant; but it renders it also gluey, difficult to dry, and imparts to it a disagreeable odour.

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* M. Tingry recommends melting the copal by a gentle heat, and pouring it into water, by which means it is separated from any mixture of oil, and rendered more soluble in alcohol, or spirits of turpertine.

By dissolving 6 oz. of sandarach, 4 oz. of elemi, 1 oz. of animé, half an ounce of camphor, in 32 oz. of alcohol, we will obtain a more supple, solid varnish, and equally brilliant as the two former.

The following composition is used with great success for varnishing wainscot, iron-work, grates, and the ballustrades of staircases.

	oz.
Sandarach . .	6
Shell-lac . .	2
Resin . . .	4
Pure turpentine .	4
Alcohol . . .	32

Pulverized glass as usual. The cabinet makers content themselves in general with the employment of wax for rubbing over furniture; which by repeated friction, in this way, acquires a certain degree of polish. But the application of varnish renders the wood more shining, and though it possesses the inconvenience of scaling off, and being easily scratched, it is nevertheless used for polishing our most valuable pieces of furniture.

M. Tingry has made known a process by which to all the qualities of good varnish are united the advantages of wax. It consists, in melting over a slow fire 2 oz. of white wax, and adding to it 4 oz. of essence of turpentine, after it is reduced to a state of liquefaction; it is then stirred till it be perfectly cold; in which state it is used for waxing furniture. The turpentine is readily dissipated, leaving the wax in a very divided state, and possessing the brilliant glossy quality of varnish.

The varnish employed for violins, and some particular kinds of furniture made of rose wood, acajou or plumtree, is composed of 2 oz. of seed lac, 4 of sandarach, 1 of mastich, 1 of benzoin, 2 of turpentine, and 32 of alcohol.

If in place of white resins, gamboge, dragon's blood, or some other colouring substance be employed, such as turmeric and saffron, we impart to varnish the different colours of the bodies to which it is intended to apply them.

The following composition is of a permanent and beautiful golden orange colour.

Three fourths of an ounce of turmeric, and twelve grains of oriental saffron is infused for twenty-four hours in 20 oz. of spirits of wine;

this infusion is then poured on a well pulverized mixture of three fourths of an ounce of gamboge, two ounces of sandarach, an equal quantity of elemi, one ounce of dragon's blood in tears, and one ounce of seed lac.

This varnish is used with the most complete success for covering mathematical instruments, and utensils of copper, iron and steel. The metals must be heated previous to its application.

A fine golden colour may also be imparted to brass by the following varnish.

	oz.	gr.
Seed lac . . .	6	—
Amber and gamboge each	2	—
Extract of red santal .	0	24
Dragon's blood . .	0	60
Oriental saffron . .	0	36
Alcohol	36	—

The amber, lac, gamboge, and dragon's blood, are triturated on a porphyry, and the extract of santal dissolved in the tincture of saffron.

SECTION II.

Of the Combinations of Alcohol with rectified Spirits of Turpentine.

When spirit of turpentine forms the solvent of resins which enter into the composition of varnish, the name of *essential varnish* is given to it; like alcohol, spirits of turpentine dissolves resins, like it also turpentine is quickly evaporated, leaving on the body a coat of the resins which it held in solution.

Spirits of turpentine must not however be confounded with alcohol, neither in respect to its solvent properties, nor in the effects it produces. Alcohol imbibes the colouring principle of indigo, turnsole, red santal, saffron, &c. while turpentine has no sensible action on these substances. The turpentine attacks copal, which resists, in its turn, alcohol. The *essential varnish* is more pliant, stronger, and more solid; it is less liable to scale, and is capable of receiving a higher polish. The varnish prepared with spirits of wine cracks and scales more readily; the alcohol is more

rapidly dissipated, leaving the resins possessed of all their original properties; whereas the turpentine remains in combination with them to a certain point, and imparts to the resins dissolved in it a gluey character foreign to their nature. The essential varnish is then possessed of peculiar characters, which under certain circumstances, renders its use extremely important.

It is this *essential varnish* which is alone applicable to pictures. It is evident that in this case the varnish should be colourless, supple and gluey, very transparent without being too glossy, so as to reflect the light. The following varnish appears to combine all these advantages.

	oz.
Purified mastic . . .	12
Pure turpentine . .	$1\frac{1}{2}$
Camphor . . .	$0\frac{1}{2}$
Rectified spirits of turpentine	36
Pulverized white glass .	5

The camphor is broken into small portions, and added to the turpentine when the solution of the resins is completed.

A coloured varnish is also prepared with spirits of turpentine which is of great use in glazing leather, wood and metals. It is composed as follows:

	oz.	
Seed lac	4	
Sandarach	4	
Dragon's blood . . .	$0\frac{1}{2}$	
Turmeric and gamboge each	3	36 gr.
Pure turpentine . . .	2	
Pulverized glass . . .	5	
Spirits of turpentine . .	32	

The dye is first procured from the colouring substances by infusion, and the resinous matters added afterwards.

By altering the proportions of different articles, and adding other colouring principles, such as saffron, the colour of these varnishes may be infinitely varied.

The drying nature of the resins which form the basis of these varnishes, does not enable us to unite all the brilliancy of which they are susceptible, with the necessary degree of solidity.

Copal appears to possess, in this respect, all

the qualities we could desire, and various experiments have been lately made with the view of discovering a method of dissolving it. M. Tingry found that it may be readily dissolved in ether by the following process.

Half an ounce of copal very finely powdered is introduced gradually into a flask containing two ounces of ether. The flask is then closed, and the mixture agitated for half an hour, after which it is left in a state of repose. When on shaking the flask its internal surface appears covered with small waves, and the liquor is not clear, we may conclude that the solution is imperfect, and must therefore add to it an additional quantity of ether.

This varnish is of a pale citron colour.

Ether can dissolve a fourth, and at the least a fifth of copal.

This varnish is applied with a brush; but as the ether is too speedily dissipated, especially in a warm temperature, it is found useful to cover the substance over to which it is applied with a slight coating of volatile oil; afterwards wiping it carefully off with a piece of linen. That which remains is sufficient to retard the evaporation of the ether,

This varnish forms such a hard coating to metals and wood, that the greatest friction, or the most violent strokes can make no impression on it.

Copal may also be dissolved in essential oil of turpentine and forms a varnish, having the same qualities as the former. But as the spirits of turpentine of commerce do not always possess this solvent quality, it is necessary in this case to expose it to the sun for some months in bottles closely corked, leaving an empty space of some finger-lengths between the liquid and the cork.

Eight ounces of this composition is then put into a matrass, and placed in a water bath carried to ebullition, after which one ounce and a half of powdered copal is gradually added to it; at the same time the matrass is moved in a circular direction. The matrass is then removed from the bath, and the liquor left to repose for some days, when it is drawn clear off and filtered through cotton.

The solution of the copal may be facilitated by the intermedium of some volatile oils. With this intention two ounces of spirits of lavender are heated over a gentle fire in a matrass, to

which is added, by slow degrees, one ounce of powdered copal; the mixture is then stirred with a wooden rod, till the copal disappears, when they pour in at three different times six ounces of spirits of turpentine nearly brought to the boiling point, stirring it during the whole time without interruption.

This varnish is of a golden colour, very solid and brilliant, but of a less drying nature than the preceding. There is another very valuable copal varnish which is employed in all cases where great solidity, suppleness, and transparency are requisite, and which is employed, for example, to varnish metallic plates, which in some cases are used as a substitute for glass.

To prepare this varnish, six ounces of spirits of lavender are put into a small matrass, with one dram of camphor; and exposed to the fire until they boil, when two ounces of powdered copal is added in very small portions, care being taken constantly to stir the mixture. When the copal is well incorporated, the boiling spirits of turpentine are added, and the boiling continued till the varnish acquires the requisite degree of consistence.

CHAPTER XXIII.

Of the Combinations of Fixed Drying Oils.

SECTION I.

Of the Combinations of Fixed Drying Oils with Resins.

FAT varnishes are formed by dissolving resins in fixed drying oils.

These varnishes are very hard, but extremely difficult to dry, though combined with the essential oil of turpentine, to facilitate the desiccation.

In work-shops where fat varnishes are employed to cover iron, copper, and other metals, stoves are found necessary to hasten the desiccation since otherwise the operation would prove tedious, and the varnishes would never completely dry.

The two substances most generally employed

in the composition of fat varnishes, are copal and amber.

The most simple fat varnish is prepared by dissolving 16 oz. of copal in 8 oz. of lint-seed oil, rendered drying by the usual process, and 16 oz. of the essential oil of turpentine. After liquifying the copal in a matrass, over a common fire, the boiling lint-seed oil is added to it.

When these substances become thoroughly incorporated, the matrass is removed from the fire; it is then shaken till the heat has abated, when the heated oil of turpentine is added to it. After straining the whole while hot, through a linen cloth, the varnish is put into wide mouthed bottles. It becomes greatly improved by keeping.

An excellent varnish may be obtained by digesting together 6 oz. of copal, 24 oz. of drying lint-seed oil, one and a half oz. of Venice turpentine, and 6 oz. of the essential oil of turpentine. This solution forms a beautiful transparent varnish, which, when properly applied, and slowly dried, is very hard and durable.

Since the discovery of balloons, many experiments have been made with the view of dissolv-

ing the caoutchouc; so as to render it applicable, as a varnish, to the materials of which they are constructed. Macquer had long ago pointed out the solvent property of ether; since which time fixed and volatile oils have been successively employed with the same intention, but the process most generally adopted at present consists in dividing the caoutchouc into small slips, and throwing them into a matrass placed in a sand-bath; on the mass becoming liquefied, there is added the boiling lint-seed oil, and afterwards the heated essence. These three substances are employed in equal proportions. When the varnish becomes cold, it is passed through a linen cloth. This varnish dries slowly.

Lint-seed and nut-oil, rendered strongly drying, form a varnish without the addition of any other matter. Lint-seed oil inspissates, hardens on exposure to air, and assumes nearly all the characters of caoutchouc, when applied in layers or coats upon bodies of any kind.

These two oils, mixed with lamp-black, and the carbonaceous matter resulting from the combustion of a portion of the oil itself, form what is termed printer's ink.

Printer's ink ought to be so thick as not to run; it ought to dry so quickly as to become indelible as soon as it is applied; it should be neither soluble in water, nor sink when applied to wet paper; and its colour should be of a shining black.

Nut-oil is very generally employed in the formation of this ink. For this purpose, a kettle, provided with a strong lid or cover, is two-thirds filled with the oil above mentioned. Heat is then applied, after putting on the cover. The vapours which escape are inflamed; the lid is covered with wet linen cloths; and after supporting the combustion, during some time, the fire is gradually withdrawn; the vessel then is cautiously uncovered, after which the oil is stirred, for a considerable time, with an iron spoon. The fire is then re-kindled, but not made to burn with the same force as before; and when the oil is thoroughly heated, half a pound of dried crusts of bread, and six or seven onions are put in for every 50 lbs. of the oil employed. The caldron is again covered, and the mixture boiled over a gentle fire, during three hours. The coction is supposed to be carried to a sufficient length when the cool-

ed drops are adhesive and stretch into threads on opening the fingers. When this effect is not produced, the coction must be renewed. The varnish is purified by passing it several times through a linen cloth.

There are makers of varnish who add turpentine and litharge to the oil; but this mixture is attended with the inconvenience of rendering the oil glutinous and clammy.

In order that printer's oil be good, it must be kept for some time; by which it acquires brilliancy and consistence.

The ink used in copper-plate printing ought to be more consistent than that employed in book-printing. The varnish is prepared in the same manner, with this difference only, that in place of suppressing the combustion, it is excited and supported, till the oil be rendered glutinous, like a very thick syrup. The combustion is even maintained for half an hour after the caldron has been removed from the fire. The combustion is afterwards suppressed, by putting on the lid, covered with wet linen.

The varnish used in book-printing is coloured with lamp-black, which is mixed with it

in the proportion of two and a half ounces to sixteen of the varnish. In the preparation of this mixture the greatest care is employed; and for this purpose, the lightest black is preferred.

The lamp-black is mixed with the oil used in copper-plate printing, by means of a mullar and marble. The heaviest lamp-black is employed.

Different colours may be imparted, according to our inclination, to printer's varnish. For this purpose it is sufficient to inspissate the oil by heat and combustion, by employing less agitation, in order to avoid impregnating it with the smoke, which would blacken it. The colouring substances employed are Prussian blue, vermilion, carmine, orpiment, lac, mastic, gamboge, &c.

When undulations, or asperities occur on the surface of varnishes, if they are hard, such as those which proceed from the solution of copal, or amber in drying oil, they are burnished at first with pulverised pumice-stone, spread upon a piece of white serge, formed like a bung. We go over all the coloured surface with this bung, dipping it frequently into wa-

ter, with the view of enabling us to judge of the polish, and of rendering the action of the stone more smooth and uniform. Upon this operation being finished, very fine tripoli, softened with a little oil, is applied by means of a bung formed of serge, or doe's skin. The greasy matter is afterwards removed, by going over it with piece of soft linen, dipped into bran or flour.

CHAPTER XXIV.

Of the Art of Dyeing.

THE processes employed daily in our manufactures to deprive a body of its colouring principle, and to fix it upon another body, constitute the art of dyeing.

The knowledge of the laws, according to which all bodies appear coloured, from the property which they possess of reflecting the rays of light decomposed at their surfaces, engage very little the attention of the manufacturer.

His object is merely to extract the colouring principle, to transfer it to a stuff, and to render it permanent. It is therefore of essential importance for him to know what is the colouring principle, what is the nature of the stuff on which he intends to operate, and what are the mordants necessary to be employed, in order to render the colour durable.

SECTION I.

Of the Colouring Principle.

The property which substances possess of uniformly reflecting one or more rays of light form *coloured bodies*. These coloured bodies transferred to a white body, to which they impart their proper colour, form, in this way, *colouring principles*.

These colouring bodies transferred to bodies already coloured, confound or mingle their colours with that of these same bodies, and hence is produced a *mixt colour*.

The aptitude, or faculty of reflecting particular rays, is of little consequence. There are some bodies which display different colours according to the angle under which they are seen; while there are others, the mere pulverization of which changes the colour, without altering their nature.

Nothing more is necessary to enable us to form a judgment as to the facility with which the dispositions of bodies become changed in their property, of reflecting different colours,

than to cast a cursory glance on the phenomena attendant on the oxydation of metals. Thus we behold successively appearing in them blue, yellow, red, and black, from almost imperceptible differences in the proportion of the oxygen with the metal.

The same phenomena are still more observable in vegetable and animal bodies, the colours of which appear or disappear according as the light acts upon them.

The colouring principle must not, therefore, be regarded as a particular colour, existing separately and distinctly from the coloured body. It is merely a faculty which the constituent parts of bodies possess of reflecting particular rays of light decomposed at their surfaces This faculty may be variously modified by changes produced in the arrangement of the molecules, by the proportions between the constituent principles, &c.

We cannot foretel what may be the colour of a compound body, from the nature of the principles which compose it, when not previously ascertained by experiment. Frequently two colourless bodies form a coloured compound, as may be observed in metallic oxyds,

of which the metal and oxygen are without colour. Hence, it appears, that we can only ascertain, by a series of well conducted experiments, what colours may be produced by the combinations of different bodies.

The colouring principles being as numerous as the coloured bodies, we may readily perceive how limited must be the conception of those chemists who see nothing but extracts or resins in colouring substances.

The colouring principles are, every where, either simple or compound. They are regarded as simple, when the colour cannot be decomposed; such as blue, yellow, red, to which we we may add the green and black furnished by vegetables. They are regarded as compound, when the colour results from the combination of several simple, or primitive colours; such as violet, common green, &c.

It seldom happens that the simple colours, which, by their combination, form a compound colour, possess the same fixity, and are acted on in a similar manner by re-agents; hence we are able to decompose a compound colour, and extract from it the elements separately.

Hence may be explained, why a green colour

becomes, in time, blue or yellow, according as these two principles possess more or less fixity.

By changing the proportions of the elementary colours, a variety of different shades may be obtained; and in this way, by varying the mixture of green and blue, all the different shades from the lilac, to a very deep violet green, and nearly black, are produced.

The colours of bodies often proceeds merely from very slight modifications, produced by the action of light on their surfaces, as may be seen in the colours of fruits, flowers, and insects.

Sometimes the colour of bodies appear to be more deeply seated, as in substances, which are always of an uniform colour, when sheltered from the influence of air and light. Roots furnish us with examples of this kind.

In general, the colour of bodies, when produced by the effects of light, is fugaceous, while that of substances protected from its influence is fixed and susceptible of forming good colours.

It may be considered as an established principle that colour is so much more durable as the excipient resists more powerfully the in-

fluence of air, heat, and water. Hence it is, that resins, fecula, and metallic oxyds retain their colours better than mucous, and extractive matters, &c.

It must not however be inferred from this principle, that a good and permanent colour may not be obtained by employing certain mucous, or extractive matters; but then it is necessary to furnish it with a new base, so as to change the nature of the body, and consequently its affinities.

Hence we are led to conclude, that the fixity of a colouring principle does not depend on its inalterability, but on the nature of the mordant with which it is combined, and on the affinities of this last combination with the stuff to which it is transferred; while the changeable nature of the colouring principle rests on the character of the excipient in which it is naturally held.

In regard to the nature of the coloured principles, the solvents ought to be greatly varied; water, acids, and alkalies are those most generally employed. Alcohol is seldom used, except when we wish to act on the colour of very small bodies.

Of all these vehicles, water is the most common, because few of the colouring principles are insoluble in it.

Alkalies are employed to dissolve the colouring matter contained in indigo, in the flowers of bastard saffron, &c.

The acids are used, in some cases, to dissolve certain colours, and particularly to precipitate the colouring principles from their solutions in alkalies.

Much has been written on the effects produced by waters in dyeing. And nothing is more common than to refer the brilliancy of some colours, and the poverty of others to this cause.

Without adopting implicitly what has been published on this subject, it must be allowed that waters contribute essentially to the quality of dyes; and we may even add, that different colours, as well as the same colours in different states, require that waters of very different natures should be employed.

To establish this second proposition, it is sufficient to take a cursory view of the principal operations of dyeing. If the object is to scower, or cleanse any stuff by soap, or alkali,

the water must be pure; since otherwise the soap is decomposed by earthy salts, and there is formed a combination of oil and earth, insoluble in water, and incapable of producing the effect expected. The alkali likewise decomposes the earthy saline matter, becomes saturated with the acid, and produces no further effect, while the earth being set free, combines with the stuff, and changes its colour.

Still and standing waters are, in general, the most saturated with earthy saline matters.

Rapid and running waters are much more pure.

There are nevertheless some foul and almost stagnant waters which are greatly celebrated in dyeing, because the putrid animal vegetable matters suspended in them operate to form ammonia and sulphuretted hydrogen, which precipitate the earthy and metallic principles.

Stagnant waters possess moreover the advantage over running waters in washing cotton stuffs, in order to free them from the alum or oil not fixed in their texture; for, in this case, it is necessary to moisten all the parts of the stuff, equally, to extract from it all the uncombined mordant; and it is difficult to accom-

plish this end by the employment of running water, without the colour being meagre, and blended with different shades.

Clear and running water ought to be preferred for the cleansing of stuffs when taken out of the dyeing bath; they effectually remove every portion of matter not fixed in the stuff, and develop the colour in full perfection.

Waters impregnated with calcareous salts are particularly prejudicial to the dyeing cotton of a red colour. The lime which is precipitated by the galls, alum, and washing, tarnish and obscure the colour to such a degree that it is almost impossible to revive it.

But in as far as calcareous earth tends to augment the solidity of the red colour and its modifications, selenitic waters do not prove injurious, where the object is to obtain a dark colour.

As calcareous salts change scarlet into crimson, it is obvious when this colour is the object, the use of selenitic waters must prove more advantageous than hurtful.

Calcareous salts dissolved in water, exclusively of counteracting a change in colours, possess the inconvenience of weakening the solvent

action of the liquid holding them in solution; whence it results, that the colouring principle is dissolved in a less quantity than in selenitic water.

It appears to me an unquestionable fact, that the waters which keep the earths suspended, are less prejudicial than those which hold them in solution. In the first case they do not adhere to the stuff, while in the second they are precipitated by means of a double affinity, and enter into combination with a mordant which transfers and fixes them on the stuff.

Of all the earthy principles which are found in water, lime is the most common, and that alone which can prove injurious. Alumine and magnesia never produce any bad effect.

The sulphate of iron is almost the only metallic salt found existing in waters; and in however small a proportion it be contained, it produces very sensible effects upon colours, particularly upon silk and cotton stuffs; those of wool are much less affected by it.

The sulphate of iron acts, especially upon stuffs that have been subjected to the operation

of galling, and produces brownish tints which modify all the colours imparted to them.

The nature of the colouring principles not only regulates the choice of the solvents to be employed, but also enables us to assign to each its proper use.

Thus coloured resins are dissolved in alcohol, and form the colouring principle of varnishes.

Metallic oxyds when fused with alkalies, earths, &c. are employed to stain glass, enamels, and pottery-ware.

Oils and fecula are dissolved in alkalies or lime; and the extractive principle is transferred to the stuff by means of water.

As we are yet very little acquainted with the cause of colour in bodies, we shall confine ourselves to relate some facts relative to the mode in which the colouring principle is developed.

In proportion as oxygen enters into combination with a metal, its colour becomes changed, and a difference in the proportions suffices to produce blue, yellow, red, black.

The effect produced by the oxygen is more or less durable according to its affinities with the metal.

Sometimes the colour disappears with the oxygen disengaged by a gentle heat, more frequently, however, the combination is so intimate, that it supports, without suffering any change, a heat approaching that of vitrification.

Excepting some resinous bodies, and some extracts, the colours of vegetables are obtained by subjecting them to fermentation. Indigo, wood, turnsol, &c. furnish examples of this kind.

In all cases wherein a blue colour is produced by fermentation, it appears to me that carbon acts a chief part. Indigo contains twenty-three parts of carbon to forty-seven of colouring matter; vegetables yield by solution a carbon of a very fine blue; and it seems probable that when the blue colour is obtained by fermentation, the carbonaceous matter is nearly set free, and remains combined with an oil, which gives additional fixity to the colour, and indicates the most suitable solvent.

From experiments which I made in 1795, with the view of adding some vegetables to the list of those which furnish blue colours, I discovered that *goat's rue, sainfoin, chick peas,*

and *lucern*, when treated like indigo, yielded a blue colour, but I did not succeed in precipitating it, which may perhaps be attributed to the very great proportion of extractive matter, rendering it viscid, and causing it to froth in the manner of soap water, after the first fermentation.

This liquor exhales the odour of stercoraceous matters in a state of putrefaction.

I have always been of opinion that by torrefying vegetables, so as partially to carbonize the extractive matter, we might succeed in obtaining the coloured fecula; but hitherto I have not attempted such a regular series of experiments, which can alone produce satisfactory results.

It seems the blue colour is so much more fixed in vegetables as the carbonaceous principle is more abundant.

When the carbon is combined with an oil, as in indigo, it is neither soluble in water nor alcohol; but when the mucous matter is united with it, as in turnsol, &c. the colouring principle is soluble in water alone.

SECTION II.

Of Mordants.

Few colouring principles possess such decided affinities as to form a permanent union with a stuff on contact or application alone.

There are cases where the same vehicle which deposits the colour can also erase it; but this kind of daubing does not deserve the appellation of *dyeing*.

Some metallic oxyds, especially those of iron, as well as several astringent and resinous substances, are susceptible of contracting a kind of adhesion to stuffs without any intermedia. But in general the adhesion of the colouring principle with a stuff is facilitated by the intermedium of a third body which is termed a *mordant*.

Most chemists who have written on the subject of dyeing before chemical science had attained its present degree of perfection, have applied the most absurd theories to the action of *mordants*.

Hellot conceived, that the preparation given

to stuffs in order to dispose them to receive the dye, acted by cleaning and opening their pores; and he adds, that it is probable the colouring particles are *encased* in these pores in the same manner *as a diamond is set in the collet of a ring*.

Macquer has adopted the same theory; and we owe to Bergmann and Berthollet the improvement of conducting all the operations of dyeing on the general laws of affinities.

According to the principles adopted by these two celebrated chemists, mordants must be regarded as the intermedia of the union or affinity between the colouring principle and the stuff.

In combining separately the colouring principle with the mordant, or disposing this last on the stuff, we produce compounds endowed with affinities, in consequence of which they contract an union with bodies, which by themselves would have had no affinity with any of their constituent principles.

The affinity of the mordant with the stuff, and with the colouring principle, may be rendered evident by direct experiments.

M. Berthollet has shewn that wool boiled with alum decomposes a portion of this salt,

and combines with the alumine ; he has shewn further, that the undecomposed portion of the alum, dissolved a little of the animal substance.

The same chemist has demonstrated that cream of tartar and alum are not decomposed by boiling, though the cream of tartar is rendered more soluble by this mixture. He adds, that when a mixture of these two salts are boiled with wool, a decomposition takes place, which proves that the wool acts as an intermedium.

Wool boiled with alum alone is hard to the touch, but treated with cream of tartar and alum it feels soft, and receives a fuller and more vivid colour.

The decomposition of alum by animal substances dissolved in alkali, prove that alumine combines with them. Thus, if a solution of alum be mingled with isinglass, and precipitated by an alkali, the alumine unites with the gelatine, forming a semi-transparent body which dries with difficulty.

The decomposition of alum is not so readily produced by vegetable substances; though the astringent principle certainly decomposes it;

and when this principle is deposited on a stuff, which after being dried is put into a solution of alum, a combination takes place between the alumine and tannin.

In this case the concurrence of animal and vegetable substances produces a more perfect decomposition of the alum, as is evident in the preparation to which cotton cloth is subjected, in order to render it fit to receive a madder red.

To demonstrate the great affinity between alum and the colouring principles, it is sufficient to observe, that it forms the excipient of all the colours known in the arts under the name of *lacs*.

When any coloured body is boiled in a solution of alum, and precipitated by an alkali, the alumine combines with the coloured precipitate and forms a *lac*.

Alumine, according to the method of M. Thenard, may even be very intimately mixed with metallic colours, such as prussiate of iron, oxyd of cobalt, &c.

In order that any body be fit to act as a mordant, it is not sufficient that it possess an affinity with the colouring principle, or with

the stuff; it must also be perfectly white, otherwise its colour, mixing with that of the colouring principle, would thus produce a mixed colour.

There are cases, however, in which certain bodies can serve at the same time as a mordant and a colouring principle; thus the oxyd of iron is employed along with a madder red, in order to dye cotton violet, and which, if employed alone, would produce a very deep nankeen colour.

Mordants ought to be little subjected to change by the action of the air and water; as otherwise they render the colours cloudy.

We must not judge of a mordant, disposed on a stuff, and combined with the colouring principle from its original properties, as the new combination imparts to it new qualities; and it is according to them that an opinion must be formed respecting it. Thus, for example, alumine which is very soluble in xed alkalies, when uncombined with any other substance, becomes insoluble when, in the cotton prepared for Adrianople red, it is united with tannin and oil.

At present the two mordants most fienerally

employed are, alum and muriate of tin. By decomposing alum by the acetate of lead, an acetate of alumine is obtained, which is preferable to alum, because the alumine is more easily disengaged from it, and the acid thus liberated is less corrosive.

The oxyd of tin possesses very marked affinities with the colouring principles, of which it heightens the colour, especially those of scarlet and madder red.

The oxyd of iron displays more decided affinities with the stuffs, with which it combines in an almost indelible manner.

But as it is naturally coloured, it can only be employed in dyeing compound or mixed colours; in this last case the colour is harsh, unless it be softened by dipping such red stuffs in a solution of alum saturated with potash.

The oxyd of copper is also employed as a mordant, but most generally in conjunction with iron in dyeing black; sometimes it is used alone in dyeing cotton of a yellow colour.

Lime, and all the calcareous salts may be considered as mordants; it is true they darken or obscure reds, but they give a brilliancy to

the astringent principle, heighten blues, particularly metallic blues, and impart fixity to all colours.

The most complicated mordant employed in dyeing, is that used for the Adrianople red ; it is composed of alumine, oil, and the astringent principle. This combination of three bodies, which is successively formed by the numerous operations to which the cotton is subjected, possesses none of the properties of the three constituent bodies. And though the madder red may be fixed by any one of these three substances separately taken, yet the same degree of fixity is not imparted to it as when this triple combination is produced.

The best mordants are those which have not only a decided affinity with the colouring principle, but also with the stuff; and it is this property which renders alum preferable to all the other salts; but, as in general they have a greater affinity with the colouring principle than with the stuff, we first apply them to the stuff, and afterwards expose it thus prepared to the action of the colouring principle.

If we pursue a contrary course, a lac will be formed, or the affinities between the alum and

the colouring principle will be saturated, and exert no further action on the stuff.

The mordant then applied to a stuff, first exerts its action on the stuff and combines with it; after which it attracts and retains the colouring principle.

The stuff can only imbibe a certain portion of alum, so that when it is completely saturated with this salt, it ought to be rinced through water, in order to free it from that portion of the alum which is not fixed; since, without this precaution, the superabundant alum will remain in the bath, and absorb the colouring principle, to the prejudice of the stuff.

When the stuff is not washed after the process of aluming, it is boiled in the solution, or preserved wet for some time, in order to produce a more intimate union between it and the alum.

These processes are only proper for the preparation of woolen stuffs, which have more affinity with alum than those made of cotton or flax.

The affinity of mordants with the stuff, is sometimes so great, that nothing more is ne-

cessary but placing it in their solution, in order fully to impregnate it with them.

Cotton dipped in a solution of sulphate of iron, for example, almost instantaneously assumes a nankeen colour; and when the oxyd is suspended in the solution, it is sufficient to put the cotton into the bath for a short time, to fix it on the stuff, and to render the bath perfectly transparent.

Although it is the general practice to impregnate the stuff with the mordant before the application of the colour, there is nevertheless exceptions to this rule; for example, in the manufactures of printed linens, when the object is to impress on the same stuff several different shades of blue, they first apply the colours with glue, and afterwards dip this species of painting successively into lime water, the solution of the sulphate of lime, and the lixivium of potash.

When the colours are fixed by this means, the stuff is transferred into a bath, slightly acidulated by sulphuric acid, which purifies and whitens those portions of the stuff which have not been printed.

The mordant generally unites two proper-

ties, that of fixing the colour, and imparting to it brilliancy.

If cotton, impregnated with the acetate of alumine, be dipped into a bath of quercitron, of a muddy dull colour, we see it immediately assume a brilliant yellow cloud, at the same time that the cotton becomes coloured.

When this composition is poured into a bath of cochineal, the colour instantaneously changes, and acquires the beautiful tint natural to scarlet.

In this case, the oxyd of tin combines with the colour, and forms a compound, having such a strong affinity with the wool, that it is sufficient to plunge it into the bath, that it may extract all the colour.

In the dyeing of some colours, it is necessary to employ separately one mordant for the stuff, and another for the colouring principle. For example, when we wish to impart a crimson colour to wool, the stuff is prepared with 5 oz. of alum to the pound of stuff; and the colouring bath is composed of 5 oz. of cochineal, and 2 ounces and a half of tartar; to this mixture is added, after it has reached the boiling point, 10 ounces of the solution of tin.

SECTION III.

Of the Nature of Stuffs.

All stuffs, subjected to the dyeing process, are formed either of animal or vegetable substances.

Wool, and silk, must be ranked in the first class; cotton, flax, and hemp, belong to the second.

Wool and silk are extremely soluble in alkalies; cotton, hemp, and flax, resist very strong lixivia of these salts.

From these differences it follows:

1. That animal wool, or stuffs, cannot be scoured by means of alkalies.

2. That they cannot be impregnated with a mordant, of which alkali serves as the vehicle, as is practised in respect to cottons.

3. That it would be improper to heighten any colour imparted to wool, by potash or soda.

Wool and silk are more easily acted on by acids than vegetable stuffs; very dilute sulphureous acid burns them rapidly; the nitric

acid yellows them by an incipient combustion. The use of mineral acids are therefore highly improper in dyeing animal substances; while they may be employed with perfect safety in the dyeing of vegetables.

Animal stuffs have a greater affinity with the colouring principles than those formed of vegetable substances. It is sufficient to plunge wool, or silk, into a dyer's bath, to impart to them a very good colour. A similar immersion of a cotton stuff produces only a daubing, which is easily washed out with water, leaving scarcely a trace behind.

Animal stuffs have also a stronger affinity with mordants than vegetable stuffs. Alum is decomposed by simple boiling with wool, but it experiences almost no change on being subjected to the same process with cotton or flax. Alum applied to wool acts as a mordant, but cotton must previously be galled before it can decompose the alum.

Each of these stuffs have their peculiar mordants; the oxyd of tin combined with cochineal, possesses not the smallest affinity with cotton; while the oxyd of iron has, in its turn, a greater affinity with cotton than with wool.

Wool and silk appear to be of a more porous nature than cotton, flax, and hemp; since they are more penetrable by water, and retain in their substance a greater quantity of that fluid.

We also succeed in imparting to these first substances very full, deep colours, with little preliminary preparation.

The cause of the differences between vegetable and animal substances, appears to proceed in a great measure, from the former containing more carbon than the latter. This principle, which is very dry, compact, insoluble, and nearly indestructible, has little affinity with the colouring principles; and it is necessary to cover it with a stratum wholly foreign to the mordant, and especially to the oily mordant; in order to impart to it the property of fixing colours.

Independently of the striking characters which completely separate animal and vegetable substances, various modifications exist among different substances belonging to the same class; silk, for example, appears to be less animalized than wool; it is less easily acted on by alkalies, appears less porous, and

gives more brilliancy to the colouring principles.

Cotton is more easily dyed than flax, and flax than hemp; these two last substances are acted on with greater facility by acids than the former. From all which it is evident, that the dyeing process ought to be varied, not only in relation to the two principle divisions we have established, but that it also requires to be modified according to the peculiar nature of the different stuffs belonging to each class.

SECTION IV.

Of the Preparation of Stuffs.

Wool, silk, and cotton, are naturally clothed with a substance insoluble in water and alcohol.

Nature appears to have covered their filaments, so to speak, with a varnish, to preserve them from the action of water, and while this species of covering exists, the threads of wool, silk, and cotton, are impenetrable by this fluid.

Thus, in order to dispose these substances to receive a colour, each filament must be previously freed from the covering of which we have spoken.

This preliminary operation is known under the name of *scouring* when applied to stuffs intended to be dyed; and *bleaching* when our intention is to impart to them a high degree of whiteness.

As the operations of bleaching are strictly connected with the process of dyeing, we shall here enter into some details concerning them.

1st. Wool is naturally covered with a greasy substance, which hinders it from imbibing colours, and renders it impermeable to water.*

In order to cleanse woolen substances, and free them from this grease, they are put into tepid water, to which a quart of stale urine is added; and after being rubbed and *handled*, are taken out and hung up to drip. They are then transferred into baskets, fastened in running water, and trodden with the feet till the water assumes a milky appearance; when they

* Reaumur has observed, that it is sufficient to rub the greasy matter of wool on a stuff, to prevent it receiving any dye whatever.

are again dripped, and exposed to the air by spreading them on a sand bank until perfectly bleached.

In Spain, and at present in France, they omit the urine, and carefully wash the wool in a bath of water, so much heated that it is painful to keep the hand in it for any length of time; the same water is employed for washing different parcels of wool, until the liquid becomes perfectly thick and greasy.

In the first case, the ammonia contained in the urine forms a soap, which is washed out by the water; and the action of the air, and humidity complete the *whitening*.

When it is intended to give to silk that beautiful whiteness it receives at Lyons, it is subjected to three different operations.

1st. *Cleansing*, which consists in putting the silk into a solution of 30 parts of soap to 100 of silk, brought nearly to the boiling point.

2d. *Boiling*, this is performed by boiling the silk for one hour and a half in a weaker solution than the former.

3d. *Bleaching*, which is accomplished by placing the silk in a strong solution of soap.

At Lyons, the silk is exposed to the fumes

of sulphur, with the view of rendering it whiter, and imparting to it greater brilliancy. To this purpose the silk is hung on long poles disposed in an apartment from which air is, as much as possible, excluded. The sulphur, previously put into an earthen vessel, is then lighted and kept burning during twenty-four hours, at the end of which the chamber is opened, and the silk left to dry. This last process is never used for silks that are to be dyed.

The use of soda, and that of water heated, in close vessels, beyond the boiling point has been repeatedly proposed for whitening silk, but though frequently tried, their use is wholly relinquished, which proves that they are less advantageous than the former practices.

We owe, to Beaumé, the discovery of a process, by which the natural stiffnes of the silk is preserved, while it is rendered perfectly similar to that of nankeen with which they manufacture gauzes, blond lace, ribbons, &c.

This process consists in digesting for twelve hours, 6 lbs. of silk, in a mixture of 48 lbs. of alcohol at 30 degrees, and 12 oz. of muriatic acid, at 15 degrees of concentration.

This liquor is poured off when it has become slightly coloured, and replaced with alcohol, which we pour over the silk till no more colouring matter passes off along with it. It is then covered with a similar mixture of alcohol and acid as at first, which is allowed to stand on it two or three days, or until the silk be perfectly white. It is then freed from any remains of the acid, and alcohol by washing it in cold water.

The silk bleached by this method, and loosely dried, is without lustre. It ought to be strongly extended while dripping wet, and left to dry in this state of extension.

2. When treating of the oxy-muriatic acid we described the bleaching process in which it is employed; and shall at present, therefore, only notice the ancient methods, which are still practised in several cotton, linen, and hemp bleach-fields.

Cotton is more easily freed from its natural colour than either flax or hemp. Cotton fabrics, after being carefully washed in hot water, are placed in a copper one above another, care being taken to keep those stuffs uppermost which are most difficult to whiten. The whole

is covered with a layer of ashes, which are watered by the lixivium rendered caustic by lime. This lixivium, which is poured on cold, filters through the ashes, and gradually penetrates the cotton. It is afterward rendered tepid, and when it flows in this state into a bucket placed under the tub for the purpose of receiving it, we then throw boiling water over the whole. This process is continued for twelve hours; at the termination of which the cottons are carefully washed, and exposed for several days in the bleach-field.

I have already described the method practised in the Levant, and which I introduced into France, for bleaching cotton by evaporation. This process appears to me preferable to all others with which I am acquainted, in point of simplicity and economy. It was this which gave birth to the idea of employing it in washing linen; and the experiment made in the wash-house of Messrs. Bawens, at Bons-Hommes, upon three hundred pair of sheets from the Hotel-Dieu at Paris, proved that they were better washed, and at one half of the expence incurred by the usual method. This mode of washing has since been brought

into very general use by the exertions of Messrs. Cadet de Vaux and Curaudau.

Bleaching linen and hempen cloth is much more difficult than that of cotton; the principal bleach-fields of this kind are in the ancient provinces of Beauvoisis, in Flanders, and in Picardy.

Although the bleaching process every where consists in the alternate action of alkalies, air, and water; it nevertheless admits of various modifications, according to the nature of the linens or thread subjected to it.

For example, in the vicinity of Beauvais, the cloths are of an excellent texture, and of a reddish grey colour. Here the operation is begun by soaking the cloth in river water, and afterwards extending it on the field to dry.

It is next carried to the wash-house and lixiviated in the following manner. Tubs four feet high by six inches in diameter are provided, in which the cloth is laid, care being taken to place those pieces uppermost which require the strongest ley. The whole is covered with a piece of thin coarse linen, over which is laid a stratum of ashes, and over this is thrown several buckets of warm wa-

ter, and afterwards a boiling lixivium, composed of soda, pot-ash, and the salt procured from the combustion of the stalks and leaves of tobacco; the lixivium flows out through a bung hole formed in the bottom of the tub. This process is repeated five or six hours daily for several successive days, the cloth being taken out of the tub every morning at four o'clock and spread in the field, where it remains until mid-day. These alternate exposures and washings are continued for fifteen or sixteen days. The linen is then soaped by the hand or in fulling mills, and again spread out in the field, from which it is once more taken and put into milk. These operations are repeated five or six times, till the cloth has acquired the requisite degree of whiteness. With the view of imparting a gloss it is put through water starch and calendered before being perfectly dry.

The flax produced in the greatest part of Flanders is fine, long, and extremely beautiful. From the nature of the water in which it is soaked, it acquires a silvery hue which distinguishes it from all the other flax. It is with this flax spun by the hand that they manufacture the finer kinds of cloth.

In the bleaching-houses in the neighbourhood of Valenciennes, the linens are soaked in water for two or three days, and afterwards placed in a large tub. They are covered with a piece of coarse linen, over which is laid a stratum of soda half an inch in thickness. This stratum is covered with a second cloth, on which is poured a heated lixivium of soda, and afterwards some of the same liquor brought to the boiling point, which penetrates the mass and flows through the bottom of the tub. This water is collected for further use.

This process is continued throughout the night, and at day break the cloth is extended in the field and occasionally watered till noon; when it is replaced in the tubs and subjected to a second lixiviation; these operations continue during forty days. At the end of this period the cloth is soaked for twenty-four hours in a tub filled with sour milk, after which it is soaped, carefully washed in running water, and dried in the shade. It is then starched and calendered as already mentioned.

In Lower Picardy, where the flax is less fine than in Flanders, the cloth is of a worse texture and of a greyish brown colour.

These linens are first soaked in running water, and afterwards macerated in coppers filled with water mixed with chalk or slaked lime.

They are next dried in the field and alternately lixiviated, and exposed to the action of the atmosphere, as at Beauvais, except that the lixiviation is less frequently repeated, and the cloth remains longer exposed in the field.

When the linen is strong and coarse, it is again put, after the first lixivium, into the lime or chalk water.

In Picardy, sour milk is never employed; they merely rest satisfied with washing the cloth with soap at the end of the operations, and exposing it in the field if it be not sufficiently white.

These linens are not of such a beautiful white as the former, but they are less injured, and on that account are preferred in commerce.

When a small quantity of thread is to be bleached, the skains are put into pots with alternate strata of soft soap. It is then placed in a stove or in a warm apartment for twenty-four or thirty-six hours, when the thread is taken out of a most beautiful whiteness. If it

be not perfectly whitened by this first operation it must repeated.

To the cotton, linen, or hempen fabrics intended for dyeing, it would be useless to give that degree of whiteness; all that is necessary in this case is carefully to cleanse the stuffs, that the mordant may more readily penetrate into their pores, and that they may imbibe with greater facility the colouring principle. A hot alkaline lixivium is sufficient for this purpose.

SECTION V.

Of the Preparation of the Colouring Principle.

The bleaching or cleansing of stuffs imparts to them two qualities which fit them to receive the colour; the facility of being more easily and more uniformly penetrated by the mordant, and the colouring principle; and the property of not altering by their own peculiar colour that which is imparted to them.

But it is not sufficient to prepare the stuff, it is also necessary to dispose the colour to penetrate it; and we succeed in this by different means, all of which however must be sought for

either in the nature of the colouring principle itself, or in the mode which we follow in applying the colour.

There is no colouring principle, whatever may be its affinity with a stuff, which can produce an uniform and consistent colour, unless it be applied to it in a state of perfect solution.

To produce this solution the colouring matter must be minutely divided, and a solvent employed suitable to the nature of the colouring principle.

The first object is obtained by triturating the colouring matter in a mortar, or by means of a muller, and afterwards passing it through a fine sieve, that no gross particles may escape notice.

Colouring matters are in general divided most speedily, perfectly, and easily, by the extraction of the colour, so that a finely pulverized colour, saves time, fuel, and the menstruum in which the solution is effected.

The methods by which the division of colouring substances are produced, vary according to the consistence, the nature, and the volatility of the matters on which we operate.

Madder which is not very hard may be either bruised or cut with a knife. It cannot indeed be ground under a muller, except when in a perfectly dry state.

When the madder is sold in powder, it is of three different qualities, the worst is that prepared from the outermost bark, the second is that made from the inner portion of the root, and that of the best quality is procured from a mixture of the ligneous substance of the plant with a small portion of the inner rind or bark of the root.

When hard woods are employed, such as logwood, fernambuc yellow wood, they are reduced to chips or scales by means of a sharp instrument. In Holland and Britain the hard woods are ground in mills erected for the purpose.

These woods which are extremely useful, and even necessary in dyeing, are penetrated with so much difficulty by liquids, that they require to be steeped a long time, and even boiled for several hours, in order to render their pulverization accurate.

The barks, such as those of the quercitron, do not require such a great apparatus; it is per-

fectly sufficient to bruise them under mullers, in a manner similar to that by which tan is ground.

Cochineal is pulverized in wooden mortars, and some dyers add to it cream of tartar, with the view of facilitating the extraction of its colour in the bath. In whatever manner pulverization is performed, a subtile powder is however diffused through the work-shop where this operation is performed, which, besides proving injurious to respiration, occasions a considerable loss to the manufacturer, particularly if the article be expensive.

To prevent this loss the operation of powdering should be performed in covered places, and the matters be moistened with a small portion of water; this is the method practised in bruising, indigo which is wetted with a small quantity of water, and often with the lixivium of pot-ash; but this is the only case in which this alkali is used as a solvent.

As soon as the colouring principle is properly divided, it may be dissolved without further difficulty. But as all these principles are not of the same nature, one solvent cannot be em-

ployed for the whole of them. All known solvents, however, may be reduced to four or five, water, alkalies, acids, alcohol, and oils.

ARTICLE I.

Preparation of the Colouring Principle by Water.

Water, of all the other solvents, is the most generally applicable; with the exception of some colouring principles of a resinous and starchy nature, it dissolves every other; and possesses the advantage of only contracting a slight union with the colouring principle, so that it may readily be deprived of it, and again become limpid.

Warm water extracts a greater portion of the colouring principle than cold water. But all colouring principles do not require the same degree of heat; some of them can best be dissolved by a long protracted solution, and others require a very gentle heat. It is, however, necessary to ascertain the degree of solubility of a colouring principle at a determined heat,

in order to regulate these operations ; too long boiling, or too great a heat tarnishes the brilliancy of some colours ; while, on the contrary, too low a degree of heat frequently extracts only one part of the colouring principle. A knowledge of these circumstances is absolutely necessary to the dyer, to enable him to conduct these operations.

We have already spoken of the different kinds of water employed in dyeing, and shall here only add, that in some dye-houses they correct the bad quality of the water by mingling with them a composition of bran and water, previously fermented and soured.

When the coloured matters very finely divided in the bath become so closely attached to the cloth that they cannot be completely washed out, dyers are in the habit of either straining the bath before it is employed, or of inclosing the coloured substance in a bag, in order that the colouring principle alone may be dissolved in the bath.

ARTICLE II.

Preparation of the Colouring Principle by Alkalies.

Alkali, under which we comprehend lime, is employed as a solvent of several colours. In general those colours produced by fermentation are less soluble in water than in alkali, as may be observed in indigo, woad, &c. Boiling water dissolves only a ninth part of its weight of indigo; woad communicates very little colour to this fluid, and annotto can scarcely be dissolved in it at all, without the aid of alkali.

Alkali is besides employed as a solvent of some resinous colouring principles, such as that of the bastard saffron.

We shall shortly notice in what manner, by the aid of this solvent, we can prepare a colour to be applied to a stuff.

The workmen term an *indigo vat,* that colour which is prepared by a solution of indigo without any mixture of woad, and in which the indigo is dissolved by means of alkalies.

In order to prepare the *indigo vat,* 3 kilo-

grammes, (equal 6 lbs. 9 oz. 15 dr. avoird.) of ashes made with dried dregs of wine, an equal quantity of bran, and, 3,67128 hectogrammes, (10 oz. 8 dr. avoird.) of madder, is diffused in 40 buckets of water *.

This mixture being brought to the boiling point, they add to it 3 kilogrammes, (equal 6 lb. 9 oz. 15 dr. avoird.) of indigo previously triturated with water, and after carefully stirring it, cover up the vat The stirring is repeated every twelve hours until it become blue, which usually happens at the termination of forty-eight hours.

The bath is usually covered with a blue froth or flocculent matter.

This vat is not only employed for dyeing wool, but also silk; in the last case, however, it is necessary to augment the proportion of the indigo, from the greater difficulty with which the silk receives this dye. When we wish to impart a full blue to silk, we previously impart

* As an example, I am forced to describe a process I have seen performed with advantage. The quantities may vary in different workshops, but the proportions are always the same.

to it a ground of sorrel, and then immerse it in a strong *indigo vat*. Guhliche describes a cold vat for dyeing silk, composed of 1 lb. of indigo triturated with water, to which is added 3 lb. of lime slaked in the air; this mixture is agitated and left to repose for some hours, after which they put into it 3 lb. of sulphate of iron; the vat is then well stirred up, and covered for some hours, at the end of which 1 lb. and a half of powdered orpiment is mixed with it, and it is once more left at rest; the silk is put into it when the liquor appears clear beneath the scum. This vat may be employed for the dyeing of linen and cotton, as well as silk.

Cotton and linen are very expeditiously dyed in a vat composed as follows: three drams of pulverized indigo to a pint of soap-boiler's ley, marking from 15 to 18 degrees of concentration, is boiled in a caldron; and when the coloured particles are sufficiently penetrated, six drams of powdered orpiment is put into the bath; it is then raked, and in a few minutes becomes green, throws up a blue matter, and is covered with a pellicle; the whole is diluted with a greater quantity of water, after which it is fit for immediate use.

Sulphuret of antimony may be employed in place of the orpiment; but in this case I have never found the colour equally bright and vivid.

The vat in which orpiment is mingled differs from the other in no respect but in containing a less portion of indigo. M. Hausmann prepared a bath with 200 lbs. of water, 30 lbs. of potash, 12 lbs. of quick-lime, 12 lbs. of orpiment, and 16 lbs. of indigo. A lixivium is prepared with the three first articles, and afterwards thickened with the gum.

Hellot has described two vats in which the indigo is dissolved by means of urine, which is used in a very great proportion. In this case it is evident, that the ammonia acts as the solvent; but these methods are now no longer useful, since they are less expeditious, and not attended with equal advantage as the *woad* and *indigo* vats.

Quick-lime is sometimes substituted instead of alkalies. Bergmann recommends a vat prepared by slacking 6 drams of quick-lime, in as small a portion of water as possible; in which there is afterwards poured a solution of 3 lbs. of

sulphate of iron, and 3 drams of pounded indigo, in 2 lbs. of water. In two or three hours this vat is fit for use; it only answers for the dyeing of linen and cotton.

The joint action of lime and alkali is employed in several cases, in which a solution of indigo is required; thus in dyeing cotton, 10 kilogrammes (equal 22 lb. 1 oz. 2 drams avoirdupois) of indigo is macerated in a strong caustic lixivium. They afterwards bruise the indigo, at the same time pouring into the vat about three hogsheads and a half of water, and introduce into it 10 kilogrammes (equal 22 lb. 1 oz. 2 drams avoirdupois) of quick-lime; when the lime is extinguished they *rake* the copper, and dissolve in it 18 kilogrammes (equal 41 lb. 12 oz. 10 drams avoirdupois) of sulphate of iron; when the solution is complete they throw in the ground indigo. The vat is raked seven or eight times the same day, and after being left at rest for thirty-six hours, it is fit for use.

The celebrated *woad vat*, so generally employed for dyeing blue, is more complicated than any we have hitherto mentioned. As the opera-

tions vary in different dye-houses, I shall describe that which in my opinion is the most perfect

Four hundred pounds of woad well divided, is put into a vat seven feet in depth, by five feet in diameter.

Thirty pounds of woad is then put into a caldron, to which, after three hours boiling, they add twenty pounds of madder, and an equal quantity of bran. The ebullition is afterwards continued for half an hour, when the bath is recruited with twenty buckets of water.

The woad is withdrawn and the bath allowed to become clear, after which it is poured into the vat; the vat is then raked for half an hour; after which the tub is covered, and at the end of six hours, again raked during another half hour.

This operation is renewed every three hours.

When the blue appears in streaks on the surface of the liquor, eight or nine pounds of quick-lime is mixed in it, which the workmen term *giving bottom to the vat*. This liquor is of a deep blue, and exhales acrid vapours.

They likewise introduce into it indigo triturated with water, which is used in the pro-

portion from 10 to 30 lbs. according to the shade of colour we wish to procure.

The vat is raked from time to time until the blue froth already mentioned be formed on its surface, when it begins to work.

It is then covered with its lid, and some thick blankets, to prevent it becoming cold; after the madder is added it is never uncovered but during the time it is raked. When, however, notwithstanding these precautions, the heat suffers much abatement, we draw off a portion of the liquor from the heated bath, and pour it boiling into the vat.

When the lime is used in too great or too small a proportion, it produces troublesome accidents; in the first case the colour becomes black; the odour is pungent, and the stuff immersed in the bath comes out of a pale grey colour. In the second case, the colour becomes rusty, the matter at the bottom is raised up, the odour is fetid, and in fact a state of putrefaction has taken place.

The first state of the vat is corrected by adding to the liquor madder bran, urine, tartar, &c.; by re-heating it, leaving it at rest without having been raked; and by throwing into it one or two basketsful of fresh woad.

The putrefactive state of the vat is corrected by the addition of lime, and by rakeing, &c.

If annotto be boiled in an alkaline lixivium, its colour becomes of a bright agreeable yellow, which can be rendered of different shades at pleasure, by destroying, by means of citric acid, or alum, the effect produced on it by the alkali.

In dye-houses where much annotto is employed, it is put into a copper cullender with very small holes, after having been broken down into morsels, and the whole immersed in a copper filled with tepid water. The annotto is stirred and diffused by a stick in the form of a pestle, and passes into the bath through the holes of the cullender. This strainer is then filled with ashes from the dregs of wine, which is treated in the same manner, after which the bath is well stirred, and made to boil up two or three times, when the boiling is stopped by throwing in cold water.

When the bath is not sufficiently alkalized, it produces a brick or tile colour; in which case an additional quantity of alkali is added, it is made to boil up, and the boiling stopped as before with cold water.

The red dye, of bastard saffron, is likewise dissolved by alkalies; for this purpose it is freed from its yellow colour by carefully washing it in running water, having previously inclosed it in a strong linen bag; the residuum is then put into a fir tub or vat, and after being accurately divided, is sprinkled over with the ashes last mentioned, or with sifted soda, in the proportion of six per cent of the saffron; it is stirred during this addition, and afterwards trodden with the feet.

After this operation the saffron is put into a vessel termed a grate, of which the bottom is formed by wooden bars laid across each other, and lined with a thick linen cloth. This sieve, filled with the saffron, is placed over a tub, and cold water poured into it. The water carries off the alkali, by which the colouring principle is held in solution, and we continue to pour in more water till it comes off perfectly limpid; an additional alkali portion is then added to the remaining saffron, and the washing renewed till the whole of the colour is extracted. The colouring principle is afterwards precipitated from the alkali by means of an acid; the citric is most commonly employed for this purpose.

ARTICLE III.

Preparation of the Colouring Principle by Acids.

Acids are sometimes employed as solvents of colouring principles. The *chemical blue of Pœrner*, or the *Saxon blue of dyers*, is a solution of indigo in concentrated sulphuric acid: with the view of preparing this dye, 4 ounces of indigo, of the best quality, is put into a flask or well glazed earthen vessel, and one pound of concentrated sulphuric acid poured over it. After being well shaken, it is left to repose twenty-four hours, when 8 or 9 pounds of water is added to it.

Bergmann, who has had much experience on this subject, recommends eight parts of water to one of indigo.

This blue penetrates into stuffs with difficulty, and it is in order to correct this fault that Messrs. Quatremere and Pœrner have recommended an addition of potash, in the proportion of about a sixteenth of the acid. The

alkali renders the colour more lively, full, and penetrating.

This solution can only be employed for dyeing wool; for though when employed for silk it resists the action of water, it is readily washed out by means of soap. Linen and cotton only acquire a pale shade in this dye.

Bergmann insists on the necessity of employing the strongest concentrated sulphuric acid in the preparation of this colour. It may be used with great success when of the weight of 19 to 10 of water. I have had frequent occasion to observe, that when the sulphuric acid contained the smallest portion of nitric acid, the colour of the indigo changed to green.

Guhliche has proposed to extract the colour of yellow wood, broom, tumeric, &c. by means of the aceto-citric acid, simple acetic acid, or any other of the vegetable acids.

To prepare the aceto-citric acid, he cuts into finger-lengths, citrons deprived of their skins, which he sprinkles over with good vinegar, and afterwards expresses the juice by means of a press. The expressed juice is then filtered through paper, and exposed to the sun to cause it to deposit the gross matter; after which it is

refiltered and distilled in a sandbath, till oily streaks begin to appear on the neck of the cucurbit.

This chemist aluminizes without heat one pound of silk for 12 hours, in a solution of 2 ounces of alum; and he afterwards dyes it in a bath composed of 2 ounces of turmeric, and one part of aceto-citric acid to 3 lbs. of water.

He prepares the wool in a weak solution of alum, to which he adds a small portion of muriatic acid; the colour bath is prepared of yellow-wood, &c. dissolved in a vegetable acid, and a small portion of the solution of tin.

Guhliche likewise proposes to extract the colour from turmeric, by covering the chips of this wood with acetic acid, or aceto-citric acid; he afterwards shakes the mixture, and leaves it to repose during twenty-four hours. The liquor is then decanted off and preserved with the greatest care. New acid is poured on the residuum until the wood be perfectly exhausted.

When this liquor is to be used, warm water is added to it as long as the hand can bear it; the solution of tin is then poured into it, till it assumes a fiery colour, after which it is

agitated, and the stuff slightly galled and alumed is immersed in it.

The nitric and oxy-muriatic acids impart a yellow colour to all animal substances. The former of these acids is even successfully employed to communicate to silk and wool a very beautiful yellow colour. The nitric acid produces the same effect on madder; but the yellow thus developed disappears with the acid; while madder, though reduced to this state, is not deprived of its power of communicating its red colour to cotton.

ARTICLE IV.

Preparation of the Colouring Principle with Oils.

Oils may be reckoned among the solvents of colouring principles. Olive oil extracts the colour of alkanet. Linseed oil is the usual solvent employed in the composition of fat varnishes; and oil of turpentine dissolves by itself, resins, and serves to form varnishes.

Alcohol is almost the only solvent of resins.

We have already spoken of the uses to which it is applied, when treating of varnishes.

SECTION VI.

Of the Preparation of Mordants.

In order to convey to the reader, a clear idea of this part of the subject, which is one of the most important in the art of dyeing, since upon it depends the mode of preparing colours equally solid and brilliant; I shall divide the mordants into two kinds, viz. *earthy* and *metallic*; and conclude this article with some observations respecting the manner employed in combining them, in order to produce their effects.

ARTICLE I.

Preparation of Earthy Mordants.

Lime and alumine are the only earthy principles which are employed as *mordants*.

We employ them only in their state of com-

bination with acids, and sometimes with alkalies.

The sulphate of alumine with potash or alum, is the compound of alumine most usually employed.

Five or six kinds of alum are distinguished in commerce; but, as at the present day it is formed artificially in many establishments, it appears to us that they may all be comprehended under the two divisions of *native*, and *artificial alum*.

All alums possess equal virtues when properly prepared; for this purpose nothing more is necessary than to dissolve and re-crystallize the worst alum, in order to communicate to it the qualities of the better kinds. Thus, by solution and crystallization have the inferior kinds of alum, produced in Spain or Liege, been made to resemble Roman alum, and sold for it in the shops.

All stuffs are not equally affected by the different kinds of alum. The difference of these salts produces none upon the colours which are imparted to wool; but it is very perceptible on silk and cotton. Among the different kinds of alum, that of Rome deservedly holds the

first rank, because the calcination to which it is subjected, superadded to that it had undergone beneath the surface of the earth, operates to produce a perfect union and combination of its principles.

Alum is employed in the dyeing of different kinds of stuffs; but the mode of applying it is varied in each of them.

When silk is to be alumed, 20 to 25 kilogrammes (about 50 or 60 lbs. avoirdupois) of Roman alum are dissolved in tepid water; this solution is then poured into a tun or cask, containing from 40 to 50 buckets of fresh water, after which it is carefully stirred in order to prevent the alum shooting into crystals.

We dip into this alum bath the silk strung on cords, and drip it upon the peg, in order to deprive it of the soap adhering to it.

All the cords are then plunged into the alum, care being taken that the silk be not rolled up or entangled together, and that the cords be loose and easy, &c. They are left in the bath in this state, throughout the night, and on the following morning the silk is washed, and wrung by the hand, in river water.

In some dye-houses rods are employed in

place of cords, and the silk is dipt three or four times before being immersed in the bath. This bath can contain at once, 75 kil grammes (165 lbs. 8 oz. 7 dr. avoir-dupois) of silk. When it becomes much weakened, which the dyer knows from the taste, he dissolves in it a fresh supply of alum, which he terms *recruiting* it.

When the bath begins to exhale a disagreeable odour, it is used for the aluming of silks intended for dark colours, such as browns, maroons, &c.

The silks are usually immersed into the bath in a cold state, because it is observed that warm aluming spoils their lustre.

It is more advantageous to use strong than weak alum baths to silks, because by a strong aluming the dye is better extracted; and it is rendered more smooth and uniform?

The incrustation which forms on the sides of the vessels, in which the aluminization is performed, proceeds from the decomposition by the soap, which the silks always retain in a greater or less quantity.

When it is our object to aluminize wool, it must be previously boiled during one hour, in

a bath of water and bran, to free it from the oil; after which it is washed in cold water.

It is next transferred into a solution of alum, in which it is boiled for two hours, it is then taken out, and after being wrung, set to drain for twelve or fifteen hours; it is afterwards washed in cold water.

When it is not our intention to dye it very speedily, it ought to be covered with a wetted cloth, to maintain its humidity.

Alum is not employed singly in the aluminization of wool, except for crimson. For every other colour it is mixed with cream of tartar, which facilitates its action as we formerly observed when speaking of mordants in general.

When the wool is to be dyed of a madder red, the stuff is alumed in a bath, wherein have been dissolved four ounces of alum, and eight of cream of tartar to the pound of wool.

To dye wool with woad, according to Scheffer, the wool must be previously boiled with bran, and afterwards macerated, during two hours in boiling water, with one fourth of alum and a twelfth of tartar.

Nearly a similar process is employed in dyeing yellow with various vegetables

It appears from what has been mentioned, that boiling is employed in the aluminization of wool, and that the stuff is never completely dried before the application of the dye.

The aluminization of cotton differs besides, from that bestowed on silk and wool, in so far, that it is never performed, except in the dyeing of the Adrianople red, except in the galling; and it is performed by dissolving about a fifth part of alum in tepid water, without bringing it to the boiling point. The stuffs are then separately washed in an earthen vessel with a portion of this solution drawn from the bath, in order that it may be more regularly applied to every part of them.

After the cotton has been treated in this manner it is dried, and then carefully washed, before the application of the dye.

The sulphuric acid is not the only solvent employed in aluming stuffs. The acetic acid possesses some advantages; to this purpose we dissolve 1,46853 kilogramme (1 lb. 3 oz. 5 dr. avoirdupois) of pulverized alum in 3 pints of

water, in this solution we mingle 0,48951 kilogrammes (2 lb. avoirdupois) of salt of lead, and after agitating the liquor till it acquires a fine white appearance, we add to it 0,61188 hectogramme (3 oz. avoirdupois) of chalk, and the same quantity of potash; a violent effervescence takes place, the mixture is shaken and afterwards left to repose.

During this process there is formed a white precipitate, which consists merely of the sulphate of lead intermingled with a small portion of the sulphate of lime. The liquor which swims on the surface holds in solution much acetate of lead, *(saccharum saturni)* and a minute portion of undecomposed alum.

This mordant is that which linen printers employ to fix upon stuff the madder red. It is preferable to common alum in all the operations of aluminization, because, beside the advantage which the acetic acid possesses over the sulphuric, the acetate of alumine never crystallizes upon the stuff, and its action is more permanent and extensive.

Alkalies are likewise employed to dissolve the alumine; in which case I have even ob-

served the colour was rendered more durable. For this purpose it is only necessary to introduce into the alum bath a sufficient quantity of potash or soda, to dissolve the alumine which is precipitated. In this case there is real triple salt employed; for the sulphuric acid is not set free, it remains combined with the alumine and alkali; but on that account it adheres less strongly to the alumine, and the stuffs, the astringents, and the colouring principles precipitate this earth from it more readily.

Calcareous salts form very powerful mordants, particularly for cotton, hempen, and linen cloth; but they have the inconvenience of tarnishing their colour, on which account dyers reject them.

Pærner however employed the calcined sulphate of lime in quality of a mordant, in order to produce with cochineal a bluish clove colour inclining to red. For this purpose, calcined gypsum is boiled for one hour in a caldron, into which it is introduced when the water is somewhat more than tepid; the cloth previously soaked in the tepid water is immersed in it, and boiled for an hour; it is then allowed to remain in it till the water becomes

cold. A bath is afterwards prepared with cochineal and tartar.

If sea salt be mixed with the gypsum, the colour produced by the cochineal will be rendered of a brighter red; if we substitute the solution of tin for the sea salt, the colour will incline much more to red.

I have uniformly observed that such was the affinity of lime with the colouring principles of astringent substances, that it combined with them and brightened their colour to such a degree, that by mixing quick lime with a strong watery decoction of the bark of the black American oak, there was instantly produced a *magma* of a superb yellow colour, possessed of great durability, and from which probably great advantages may be derived in the art of dyeing.

Lime also, which is used in the preparation of indigo and woad, imparts brilliancy and permanency to this blue colour.

ARTICLE II.

Preparation of Metallic Mordants.

The metallic oxyds have a very marked affinity with stuffs almost of every kind.

There are few metallic solutions which do not make upon them such powerful impressions, that their traces are frequently indelible.

But as an oxyd, in order to serve as a good mordant, ought to present only a colourless base to the colouring principle, there are very few of them which can be employed as such.

Coloured oxyds can only be used when it is our object to obtain dark colours, or compound colours, the mordant of which then becomes one of the colouring principles. Thus the oxyd of iron fixed on cotton, converts the madder red into violet, prune, or lilac colours, according to the proportions in which it is employed.

The oxyd of tin is considered at present the most perfect mordant of all those furnished by the metals. It is principally used in the dyeing of scarlet; its application to which we shall now proceed to consider.

The *composition* for the scarlet dye, which is merely a solution of tin in the nitro-muriatic acid, is not uniformly prepared in different manufactures.

In Spain, the tin is dissolved in the undi-

luted acid, while in France, it is reduced by water. Hellot advises equal parts of acid and water; while Macquer proposes four parts of acid to three of water.

The proportion of tin employed also varies: Hellot recommends one-sixteenth to the acid; Scheffer one-fourth; Pærner one-eighth; and Macquer one-third to eight of the acid. The solutions which contain the greatest proportion of tin are brown, and produce very dark and deep colours; but if a very saturated solution be not employed for silk, the colour would be rendered much too bright.

The preparation also varies in regard to the acid. Some dyers employ the aqua-fortis, as it is produced by the distillation or decomposition of crude salt-petre; but the acid thus produced, differs according to the nature of the saltpetre, and is never of the same quality.

In many manufactures they make a solution of sea salt or sal-ammoniac in aqua-fortis; but the proportions vary from one-fourth to a sixteenth; and as the quality of the aqua-fortis is never previously well known, these mixtures

are always made by chance. Thus, sometimes the muriatic is used in too great a proportion, in which case the composition produces vinous or wine colours; while at other times it is not employed in a sufficient quantity, and then the acid precipitates, and the colour remains poor.

It appears to me, from experiments conducted with the greatest care, that the process by which we may obtain the best composition consists in employing the pure nitric acid, marking from 30 to 32 degrees, in which is dissolved without heat, a tenth of its weight of refined sal ammoniac. To facilitate this solution, the salt is broken into pieces, and put into the acid. A few days afterwards, when the solution is effected, the tin is added to it in the proportion of one-eighth of the acid employed. When the solution which takes place slowly, is finished, it is diluted with one-fourth of its weight of water, and preserved for use.

The pure nitric acid, which is employed for this composition, is known by manufacturers under the name of *Hatter's aqua fortis*.

We learn from experience, that when the solution takes place too quickly, or the effervescence is too great, the colour is less lively and agreeable than when it is effected more slowly.

When cloth is to be prepared for the scarlet dye, we put into a tin copper filled with water, 14 drams of pulverized cream of tartar, to the pound of cloth; after the bath has reached the boiling point, and the tartar is sufficiently dissolved, there is gradually added to it 4 drams of the solution of tin to the pound of cloth, after which it is boiled for several minutes.

The cloth is then put into it, and boiled for two hours; after which it is taken out and drained.

The shades of scarlet may be varied at pleasure, by changing the proportions of the cream of tartar, and the solution of tin. The tartar brightens the colour, and contributes to its permanency; but if it be added in too large a proportion, it renders the scarlet pale and dim.

There are few manufacturers who employ it in equal quantities; the proportion abovementioned is that which Pærner prescribes.

The tartar, in a small quantity, deepens the colour; while the solution of it carries to orange. According to these results we may readily impart to it the desired shades.

The solution of tin communicates only to silk, dyed with cochineal a fine crimson colour. The solution is employed in the proportion of one-sixteenth to the quantity of cochineal; and the cochineal in the proportion of one-eight to the weight of the wool.

Macquer affirms, that by impregnating silk with a solution, and afterwards immersing into a decoction of cochineal, it assumes a very beautiful colour, extremely intense, and approaching to that of bastard saffron.

By giving to silk a yellow ground, previous to the application of cochineal dye, we obtain a beautiful poppy colour, more durable and less expensive than that furnished by bastard saffron.

The solution of tin may be also employed with advantage to heighten the colour of fernambucca, and to render it more permanent.

Much use has of late years been made of the salt of tin (muriate of tin), to brighten red

colours, and serve as a mordant to them either upon silk or cotton.

The nankeen dye may be very exactly imitated, by passing cotton alternately, several times, through a decoction of tan, and a solution of muriate of tin.

M. Dambourney, of Rouen, has made much use of a solution of bismuth, which had formerly been proposed by M. Folic, of the same city. One part of bismuth is dissolved in four parts of nitric acid; this solution is afterwards introduced into a bath containing tartar, and into which is poured, at the same time, a solution of sea salt.

M. Berthollet has proved that, in whatever manner the solution be prepared, there is always formed a precipitate by the addition of water, which precipitate renders the colouring principles of a brown colour.

I tried this mordant in the dyeing of cotton red, for which its author had proposed it; but it was not productive of a greater effect than water acidulated with the nitric acid.

The oxyd of arsenic is likewise employed as a mordant in dyeing. Vogler appears to have employed with success the solution of this

oxyd with potash, in dyeing thread and cotton of a red colour. After dissolving this composition in two parts of water, he added to it a saturated solution of alum. The mixture at first becomes turbid and gelatinous; but its transparency is restored, by gradually adding to it a solution of alum. Thread and cotton immersed for twelve hours in this mordant, on being washed and dried, assume, with madder, a very deep colour.

The arsenical sulphurets, known under the appellations of orpiment, realgar, sandarach, yellow arsenic, red arsenic, &c. are all used in dyeing, particularly in the preparation of indigo.

The sulphuret of arsenic may be supplied by that of antimony; but this last does not communicate to the colour the same brightness.

The corrosive sublimate is also employed in dyeing. Wilson used it in the composition of the mordant for printing linen, in the proportion of one-eighth to the sugar of lead.

It has been shewn by Vogler, that this salt renders the colour of madder darker and more durable.

The oxyds of lead dispose a stuff to remove vegetable colours rapidly, but they tarnish their lustre. Vogler obtained a beautiful black, by galling thread and cotton impregnated with the salt of lead, by putting them afterwards into a solution of sulphate of copper, and boiling them in a logwood bath.

The sulphate of zinc is merely confined to render deeper the colours produced by madder, cochineal, and other substances. This effect is produced by the contact of air, which indicates that the oxyd operates uniformly, and absorbs oxygen,

Some metallic oxyds have so great an affinity for the substances to which they are applied, that they remain permanently fixed on them, and produce colours nearly indestructible.

Thus, for example, the oxyd of iron, though fixed in a base, when brought into contact with a stuff, imparts a nankeen, a hazel, or fawn colours; and when the particles of the oxyd of iron remain suspended in a fluid, nothing more is necessary than to dip the cotton in it, when they instantly deposit themselves and become fixed.

We may avail ourselves of this property to

dye cotton, linen, and hempen cloth, of a nankeen, fawn, and hazel colour. For this purpose it is sufficient to dip them in a solution of the sulphate of iron, acetate of iron, or any other metallic salt of that nature; on exposure to the air, after this operation, their colour gradually deepens, and even becomes harsh, if they are not immediately immersed in a solution of alum, fully saturated with potash.

We have formerly remarked, that the oxyd of iron might be employed as a mordant, to produce violet, prune, and lilac colours. It is also known that this oxyd constitutes the base of black colours; so that it may be regarded as the most generally applicable of all others, and as the most useful, whether in producing colours by itself, or in acting as a mordant, to madder red, with tannin, or the astringent principle.

The great difference between this oxyd and that of tin, is, that the latter brightens the colours combined with it, while the former changes the natural colours of the colouring principles, and produces only compound colours.

The mordant of iron is prepared differently

by different manufacturers; some employ the sulphate without any addition; others compose it by dissolving iron in vinegar; some add to it a decoction of rye flour, while others mix it with urine, herring-brine, &c.

The longer the composition is kept, the better it becomes. The celebrated blacks of Genoa, owe their superiority to the antiquity of the composition, which, for several centuries, has been attended to with religious care, and may be said to form a kind of common property.

At present, instead of the sulphuric, acetic, and other acids, is substituted the pyro-ligneous acid, which may be readily procured, and at a cheap rate, in all places where the carbonization of woad is performed on a large scale.

This acid, which, from the analysis of Messrs. Fourcroy and Vauquelin, appears to be nothing more than the acetic acid, holding in solution a certain portion of oil, possesses two advantages; that of presenting to the artist a good solvent at a low price, and that of transferring with it an oleaginous principle, which is an excellent mordant for cotton. Hence it

is justly preferred, when the object is to prepare a black vat.

There are some cases in which the affinity of mordants is modified by other substances. Thus alum is imperfectly, and with difficulty decomposed by animal stuffs, without the aid of cream of tartar. It is not perceptibly decomposed by vegetable matters; but the oil, and gall-nuts, with which we impregnate them, produce this decomposition.

The most complicated mordant with which we are acquainted in dyeing, is that of the Adrianople red.

The cotton is first impregnated with a saponaceous solution, containing an excess of oil, and mixed with animal matter. It is then galled, and afterwards alumed. Here then is a triple combination, (oil, tannin, or the astringent principle, and alumine), which adhere so strongly to the cotton, that no washing can remove it.

SECTION VII.

Of the Colouring of Stuffs.

Having already mentioned the mode by which the various colouring principles are extracted, as well as the processes by which the mordants are transferred to the stuff, preparatory to the application of the colouring matter, we shall now proceed to point out the means, by the aid of which the stuff is impregnated with the colouring liquid.

In order that the stuff may be fully and equally saturated with the dye in every part, it is necessary to employ precautions, of which few dyers are sufficiently aware, who have not acquired considerable experience in the exercise of their art.

After the stuff has been impregnated with the mordant, it is very commonly dried, and washed afterwards with care, in order to remove that portion which remains uncombined with it. Linen and cotton, of whatever colour they are intended to be dyed, with the

exception of indigo, are heated in the same manner.

But animal stuffs are carried to the dyeing vat while wet with the mordant, or soap, that has been applied to them; they are wrung by the hand, or on a wooden peg; after which they are ventilated and dyed.

The same manipulation is not employed in dyeing cloth as thread; in the first case, one roller is only used, which is placed over the caldron, in order to let down the cloth into the bath; when this is accomplished, it is rapidly turned round, that every portion of the stuff may be equally coloured.

Two men are necessary in the performance of this operation; while one turns the roller the other unwinds the cloth, and carefully extends it, that every part of its surface may be equally exposed to the colouring matter. As soon as the bath begins to boil, the stuff is immersed in it; sometimes, however, it is not even carried to ebullition, as will be afterwards pointed out.

When thread is to be dyed, it is made up into skeins, and hung on wooden rods, which are made to rest with their ends on the sides of the caldron.

As soon as the bath is prepared, they place these rods on the caldron, and afterwards let down into the bath a portion of the skeins, which they draw up by means of a pointed stick, and return them in the same manner, until every portion has been successively immersed in it.

When it is intended to carry the bath to ebullition, the skeins are strung on cords, which are attached to sticks, and left in the bath as long as the dyer may judge proper.

This process is that which is most generally employed, but it receives various modifications in respect to the different colours with which it is necessary to be acquainted.

Thus, for example, when wool is to be dyed, it is first put into a bath with water and bran, and boiled for one hour; after which it is washed.

When wool is to be dyed of a madder red, it is impregnated with a mordant of alum and tartar, and then transferred into the colour bath, which is prepared with 1,22376 hectogramme, (4 oz. 15 drs. avoirdupois) of madder, to 0,48951 kilogramme, (1 lb.

3 oz. 12 dr.) of wool; the stuff is put into this bath nearly at the same time with the madder, it is carefully turned over, and the bath gradually heated; after boiling a few minutes it is withdrawn, and carefully washed before being exposed to dry. Hellot employed 0,24475 kilogramme (9 oz. 14 dr.) of madder, to 0,48951 kilogramme (1 lb. 3 oz. 12 dr.) of wool; he kept the bath nearly at the heat of boiling water for an hour, but only it boiled four or five minutes.

Greater brilliancy is communicated to this colour, by adding to the preparatory bath made of bran, one-eighth of cream of tartar.

The red is rendered still more lively, if a small portion of the solution of tin be introduced with the mordant.

When wool is to be dyed of a scarlet colour, after having impregnated the stuff with the mordant, and prepared the dyeing vat, by the method already pointed out, the cloth is dipped into it, by means of the roller, which is turned very quickly for a few minutes; a slower motion is then given to it, and the cloth is afterwards boiled for half an hour; it is then again wound on the roller, where it is left to

drip and become cold, after which it is washed and dried in the shade.

Pærner remarked, that this colour was most beautiful when the stuff was kept in the mordant, after it had become cold, during forty-eight hours.

The materials can be prepared separately for composing the colour bath, that they may be poured into the caldron at the same time with the cloth.

To this purpose we boil in a small tin vessel, to each pound of wool 0,73426 kilogramme, (1 lb. 13 oz. 10 dr. avoirdupois) of water, and 0,76486 hectogramme (3 dr. avoirdupois) of tartar, and 0,30594 hectogrammes (1 oz. $7\frac{1}{2}$ dr. avoirdupois) cochineal.

As soon as the ebullition begins, 0,30594 hectogramme (1 oz. $7\frac{1}{2}$ dr.) of tin is added, and the whole gently boiled for the space of fifteen minutes; the vessel is then taken from the fire, and the solution poured into a large caldron of boiling water, at the instant the cloth is immersed in it.

When wool is to be dyed in a blue vat, they fix to the sides of the vat, iron or copper hoops, which are fastened with cords to the hooks on

the sides of the vat; the inner sides of these hoops are furnished with a net, and when wool is to be dyed, they put above it another net thicker than the former. These preparations are necessary to prevent the cloth coming into contact with or disturbing the deposition at the bottom of the vat.

When the caldron is furnished with this apparatus, the stuff, previously wrung out of tepid water, is put into it, and kept in for a longer or shorter time, according to the degree of strength that they wish to impart to the colour. After being taken out, it is wrung above the copper, and exposed to the air. The green colour it has imbibed in the bath is instantly changed by the action of the atmosphere.

That none of the indigo adhering to it may be lost, the stuff is first rinced in a tub; it is afterwards put through running water, and dried in the shade. When the colour is dull and muddy, the stuff is passed through boiling water, in order to free it from any extraneous impregnation.

In dyeing Saxon blue, a mordant is used of 0,76485 hectogramme (3 oz. 11 dr. avoirdupois) of alum, and 0,45891 hectogramme (2 oz.

$3\frac{1}{2}$ dr. avoirdupois) of cream of tartar, to the 0,48951 kilogramme (1 lb. 3 oz. 12 dr. avoirdupois) of cloth. After being boiled in this composition for an hour, the stuff is left in it for twenty-four hours longer.

The colour bath is prepared by pouring into boiling water 3,82430 decagrammes (15 dr. avoirdupois) of the solution of indigo in sulphuric acid, to the 0,48951 kilogramme (1 lb. 3 oz. 12 dr. avoirdupois) of cloth, which is boiled in it for twenty or thirty minutes, and after being taken out is carefully washed. Any different shade may be obtained by varying the proportion of the solution.

Yellow is usually imparted to woollen substances by a decoction of woad, but as this plant yields its colouring principle with difficulty, alkalies are employed to assist in its extraction.

Alkalies can only, however, be used for this purpose in the dyeing of linen or cotton; and their place must be supplied by marine salt, sal ammonia, and alum, when the woad is to be applied to animal substances which are dissolved in alkalies. Some dyers employ lime

to heighten several yellow colours, especially that of *quercitron*.

A more or less deep yellow may be procured by boiling woad with marine salt, lime, or alum; marine salt produces the deepest shade; alum renders the colour brighter, ammonia imparts a greenish hue to the bath, tartar gives a very pale shade, and copperas changes it to a brown.

Scheffer remarked, that by boiling wool two hours with a fourth of solution of tin, and a fourth of cream of tartar, it would afterwards become of a beautiful colour with woad.

Pærner recommends preparing the stuff in the same manner as for scarlet, with the view of imparting greater permanence to the woad colour, and rendering it more brilliant. To produce a strong colour, two parts of woad to one of wool is requisite.

Black, which is considered in dyeing as a primitive colour, may be imparted to wool by means of copperas and gall-nuts; but as by them a perfect black is slowly produced, which is besides not very permanent, the cloth is dyed of a dark blue before immersing it in the de-

coction of gall-nuts, in which it is boiled two hours. It is next put into a tepid solution of sulphate of iron, from which it is transferred to a strong decoction of logwood, and kept in it for one hour, the decoction being all the time maintained nearly at the boiling point. It is then replunged into the solution of the sulphate of iron, and afterwards into the decoction as before; and so on in succession till it has attained the desired shade of colour.

Bergmann obtained a beautiful black, by dipping 5 myriagrammes (110 lb. 5 oz. 11 dr. avoirdupois) of blue wool first into a bath of 4 kilogrammes (8 lb. 13 oz. 4 dr. avoirdupois) of cream of tartar, 8 kilogrammes (17 lb. 10 oz. 8 dr.) of copperas, 1 kilogramme (2 lb. 3 oz. 5 dr.) of verdigrise, and 5 kilogrammes (11 lb. 9 dr.) of blue woad, and afterwards boiling it in a decoction of bear's-foot.

The place of gall-nuts may be supplied by oak bark in the dyeing of wool; to this purpose, for every pound of wool should be boiled 0,95607 decagramme (3 dr.) of logwood, during one hour in 3 kilogrammes (6 lb. 9 oz. 15 dr. avoirdupois) of water; the stuff is left in this bath during the night; on the following

day they withdraw the stuff and logwood, heat the bath, and dissolve in it the third of the following composition :

	dr.	gr.	
Oak bark	4	15	— 7,96725 grammes.
Sulphate of iron	9	21	— 1,71093 decag.
Verdigrise	4	2	— 0,76486 ditto.
Common gum	2	2	— 35,58705 decig.

The stuff is passed through the bath when it is hot ; and at the end of three hours, they add the second third of the composition, and again put the stuff through it ; at the end of another three hours, the remainder of the composition is added, the bath is heated six times, and on the following morning the stuff is well washed.

By employing calcined copperas for the red instead of green copperas, very superior effects are produced, and the black is much more beautiful.

The methods employed for imparting the colouring principle of silk, differs very materially from those which are used in dyeing wool.

Dark blues, for example, cannot be pro-

duced in the indigo vat, because we never succeed in giving to this colour a sufficient degree of fulness.

Thus in order to obtain the *Turkish blue*, which is the deepest of all, it is necessary to immerse the silks in a very strong warm bath of savory before putting it into the vat.

When our object is to obtain the *royal blue*, which is also very deep and permanent, cochineal is employed in place of savory.

This last blue may be successfully imitated by first immersing the silk in a solution of 0,30594 hectogramme (1 oz. $7\frac{1}{2}$ dr.) of verdigrise to 0,48951 kilogramme (1 lb. 4 oz. 4 dr.) of silk; the silk is afterwards disposed in a bath of Indian wood, in which it assumes a blue colour, which is fixed by passing it through the vat.

Silks to be dyed blue, are usually boiled in a bath composed of 2 myriagrammes (44 lbs. 2 oz. 4 dr.) of soap to 5 myriagrammes (110 lbs. 5 oz. 10 dr.) of silk; it is carefully washed, and twice put through running water, after which it is made up into skeins, and plunged into the vat by means of the wooden roller until it has acquired the desired shade. It is

then wrung by the hand, shaken out in the air, afterwards washed, and again wrung, and hung up to dry.

When silk is to be dyed blue without boiling, the whitest kinds are chosen; they are dipped in water, with the view of disposing them more readily to imbibe the dye.

Silks intended for a yellow colour are boiled in 1 myriagramme (22 lbs. 1 oz. 2 dr) of soap to 5 myriagrammes (110 lbs. 5 oz. 10 dr.) of silk; it is afterwards washed, alumed, and exposed on rods.

The yellow bath is prepared by boiling 1 kilogramme (2 lbs. 3 oz. 5 dr.) of woad to the pound of silk during a quarter of an hour. This bath is strained through a sieve, and cooled until the hand can be kept in it; before the silk is immersed in the vat.

The woad is boiled a second time with a fresh portion of water, and employed to supply the waste and keep up the heat of the first bath, into which more silk is put till it be sufficiently exhausted.

With the view of extracting every particle of colour from the woad, and of imparting a golden hue to the yellow produced by it,

0,48951 kilogramme (1 lb. 4 oz. 4 dr.) of ashes from the dregs of wine to 1 myriagramme (22 lb. 1 oz. 2 dr.) of silk is put into a caldron; the second bath of woad is poured boiling hot on these ashes, and well stirred to hasten the solution. When the bath is become clear they gradually transfer a portion of it to the first bath, and after stirring it again immerse the silk.

A golden hue may be imparted to yellow by means of annotto.

The most beautiful red hitherto imparted to silk is that which is termed *poppy*.

The poppy colour is procured by precipitating on stuff bastard safiron held in solution by potash. With this view when silks are washed, dripped, and put on the rods, citric juice is poured into the bath till it acquires a cherry colour. It is then well stirred, and the silk repeatedly let down into it, till it has acquired a sufficient colour.

To produce a lively, full poppy, the silk is wrung on coming out of the first bath, which it exhausts, and is then put into the second. Five or six baths are requisite to impart to it a *flame colour*.

The poppy colour is heightened by putting the silk through tepid water acidulated with citric juice. A root or ground of annotto, three or four shades paler than aurora, is requisite for silks, before exposing them to the colouring principle of bastard saffron.

The poppy colour communicated by this last dye may be successfully imitated by the employment of Brazil wood.

The colour thus produced is termed *false poppy* to distinguish it from the *true*. To the silk is given a root of annotto, by boiling it with this dye, after which it is washed, passed through alum, and next disposed in a bath of Brazil wood, with which a small portion of soap-water has been mingled.

After various attempts, we still remain ignorant of the proper method of communicating a scarlet dye to silk. That imparted to it by cochineal, notwithstanding every attention, always acquires a vinous shade. If however a strong solution of tin, super-saturated with the acid he used, and the silks be alternately passed through this solution and the cochineal bath, a colour possessing all the characters of scarlet may be obtained. I have exhibited for

the last ten years, in my class at Montpelier, specimens of scarlet cloth dyed by this method.

It is likewise more difficult to impart a good black to silk than to any other kind of stuff. So many different articles enter into all the compositions employed with this view, that it is impossible to assign to each its proper use.

I have, however, succeeded in obtaining a very full, clear, permanent black, by the employment of a solution of iron, immediately after a strong galling; the stuff is then immersed in a decoction of logwood, and next into this decoction conjoined with a solution of iron and verdigrise; and this process is repeated till the black be very beautiful. With this view I employ 5 myriagrammes (110 lbs. 5 oz. 10 dr.) of silk, 2 myriagrammes (44 lbs. 2 oz. 4 dr.) of gall-nuts, $2\frac{1}{2}$ myriagrammes (66 lbs. 3 oz. 6 dr.) of copperas calcined to redness, the same quantity of logwood, and 5 kilogrammes (11 lbs. 9 dr.) of verdigrise. The silk is first wrung out of the galls, allowed to dry, and then strongly shaken by the hands in order to ventilate, and detach from it any adhering galls. The same process of rubbing, shaking, &c. is employed in respect to the log-

wood bath; and the silk is carefully washed after each immersion in the solution of copperas. In the last logwood bath is dissolved 0,61188 hectogramme (2 oz. 15 dr.) of gum arabic, to 0,48951 kilogramme (1 lb. 4 oz. 4 dr.) of silk. The black is softened by passing the dyed silk through soap and water.

I have observed by combining vegetable astringents with the gall-nuts, a softer and more agreeable colour was produced. Oak bark, a species of agaric, pomegranate bark, &c. may be employed for this purpose.

Although cotton may be dyed of every colour, that which is imparted to it by madder can only be termed a *fixed colour*. After having impregnated the cotton with the triple mordant already mentioned, and which is composed of oil, the astringent principle, and alumine, a bath is prepared of 1 kilogramme (2 lb. 3 oz. 5 dr.) of madder, to 0,48951 kilogramme (1 lb. 4 oz. 4 dr.) of cotton. Animal blood is then diffused in this bath, and on its becoming lukewarm the cotton is immersed in it.

The cotton is rubbed and handled in the

bath for about one hour, then boiled during an equal space of time, and afterwards carefully washed.

SECTION VIII.

Of the Mixture of Colours, or of Compound Colours.

Pure or unmixed colours are rarely found in nature. Red is almost uniformly found intermingled with yellow; scarlet and madder colours are composed of these two principles.

Indigo, which appears to furnish the most perfect blue, is always debased by a yellowish matter which is removed by ebullition.

But exclusively of these natural mixtures, so extremely numerous are the artificial shades formed out of them, that they may be reckoned boundless.

Here, however, we shall only enter into the consideration of the principal mixtures, all of which may be comprehended in the following classes.

1. A mixture of blue and yellow, which produces all the intermediate shades between the yellowish green and the dark green verging to black.

2. A mixture of red and blue, which comprehends all the shades from a deep violet colour to a lilac.

3. A mixture of red and yellow which embraces all the shades from a scarlet colour to that of musk and tobacco.

1. In order to form upon wool the first of these mixtures, that of blue and yellow, we first impart to the stuff the blue ground desired. The green thus produced becomes so much deeper, as the blue ground is more intense.

When the cloths are taken out of the blue vat, they are boiled in the same manner as those intended to be dyed by woad, in the usual way; and for this purpose a decoction of that substance is prepared, in which the stuffs are immersed.

The green is rendered brown by logwood, and a small portion of the sulphate of iron.

We transfer the green to the cotton by a

nearly similar process; but I have found it of advantage to employ, instead of the mordant composed of alum and tartar, the acetate of alumine.

To impart a green to silk, after boiling it with soap, it is strongly alumed; it is then slightly washed in running water, and stretched in a woad bath; as soon as it has received a proper woad ground, it is again washed, and transferred into the vat, as in dyeing blue.

In order to render the colour darker, and to vary its shade, we introduce into the bath woad, a decoction of Indian wood, of fustic, annotto, &c.

Savory is preferred to woad, when the blue vat is employed, because the colour which it imparts inclines naturally to green.

The green obtained by the solution of indigo in the sulphuric acid, is known under the appellation of Saxon green; it is more brilliant, but less durable than that which has been described.

We give to cloth the same preparation as in dyeing with woad; after it has been washed, it is boiled in the same bath for one hour and a half, with yellow wood in chips.

When the heat of the bath is moderated, so that the hand can bear it, we introduce into it about one pound and a quarter of the solution of indigo for every eighteen yards of cloth; the cloth is then immersed in it, turned at first with rapidity, but afterwards more slowly. The cloth is taken out before the bath begins to boil.

Instead of the yellow wood may be substituted woad, and the shades varied at pleasure, by varying the proportions of the ingredients.

When the blue has been dyed in the vat, it is more permanent than the yellow; whence it happens, that the green colour changes to blue through time; while on the contrary, when the blue is given by the solution of indigo in sulphuric acid, the yellow is the most durable.

II. The combination of red and blue forms the violet colour, and all the shades dependant on it.

This combination exists naturally in log-wood; it is developed in most of the lichens by fermentation; but it is not fixed in any of these two states.

To impart a good violet tint to woollen cloth, it is slightly dyed in a blue vat, after

which it is boiled, during one hour and a half, in a bath composed of 0,76435 hectogramme (3 oz. 11 dr.) of alum, and 1,52972 decagamme (6 dr.) of tartar, to 0,48951 kilogramme (1 lb. 4 oz. 4 dr.) of cloth. A bath is then prepared with 0,30594 hectograme (1 oz. 7½ dr.) of cochineal, and 1,52972 decagramme (6 dr.) of tartar, in which the cloth is boiled one hour and a half, when it assumes a blue colour.

By adding alum and tartar to the violet-bath, we may obtain all the inferior shades of lilac, dove, mallows, &c.

Pærner found the employment of the acid solution of indigo very useful; he prepared 0,48951 kilogramme (1 lb. 4 oz. 4 dr.) of cloth, with 0,917824 hectogramme (4 oz. 6½ dr.) of alum, by boiling it during an hour and a half, and then leaving the cloth to digest in the bath all the night. His dyeing bath is composed of 0,45891 hectogramme (2 oz. 3¼ dr.) of cochineal, and 0,61188 hectogramme (2 oz. 15 dr.) of tartar, which he directs to be boiled three quarters of an hour; after which there is added to it 0,4591 hectogramme (3 oz. 11 dr.) of the

solution of indigo. It is agitated, and the cloth gently boiled in it for a quarter of an hour.

The violet colours imparted to silk are divided into two kinds, *true* and *false*. To produce the first, the silk is dyed in the same manner as for crimson, except that neither tartar nor the solution of tin are mingled with the bath.

In order to produce a beautiful violet, 0,61188 hectogramme (2 oz. 15 dr.) of cochineal, is employed to 0,48951 kilogramme (1 lb. 4 oz. 4 dr.) of silk. The stuff is then passed through a weaker vat; and to impart greater beauty to the colour, it is afterwards immersed in a savory bath.

The most beautiful *false* violets are prepared with savory; they are easily known by the property they possess of becoming red by the action of acids.

A good solid violet may be given to cotton, by dyeing it with madder, and afterwards passing it through a blue vat. The beauty of this colour is in proportion to the meagreness of the red.

But the *true violet* is only imparted to cot-

ton, by combining oxyd of iron with madder red. The oxyd is applied to the cotton before immersing it in the madder bath.

It is difficult to render this colour uniform, since the iron deposited on the cotton is apt to become unequally oxydated in drying. To correct this fault, the cottons ought to be washed after receiving the mordant, and be put into the madder bath while wet.

By combining alum with the sulphate of iron, calcined to redness, in different proportions, in forming the mordant for violets, we obtain all the different shades that may be desired.

When a very beautiful violet is the object, it is necessary on taking the cotton out of the oil, to pass it into the mordant already described, then to wash it with care, and plunge it into a cold madder vat; after which it must be again washed, immersed into a new bath of madder, and boiled in it for one hour; and, finally, brightened by washing with soap.

III. Yellow, intimately combined with red, may be variously modified.

By boiling fustic in a scarlet bath, and heightening it by a small portion of cream of

tartar and the composition of tin, we may produce successively a pomegranate, orange, and jonquil colour, &c. The fustic is added to the cochineal, in proportion to the shade required. The addition of a little madder will produce a gold colour, &c.

Madder red unites very intimately with yellow, and gradually changes it from an orange to a canella colour.

If in place of the bright yellows we use plants giving out a brownish colour, such as the greatest number of astringent vegetables, we obtain more solid, but less brilliant colours. Thus hazel roots, shumach, &c. produces tobacco, musk colours, &c.

Maroon, canella, and wine colours, &c. may be imparted to silk, by logwood, fernambucca, and fustic; a decoction of fustic forms the foundation of the bath, to which is added, about a fourth of the juice of fernambucca, and an eighth of logwood. The silks are alumed before being immersed in this bath.

When brown shades are required, the Indian wood is employed in a greater proportion than the Brasil wood.

Pærner presents us with an infinite variety

of results respecting the combinations of triple colours. It may be readily perceived, that these combinations may be variously modified; but it is sufficient to ascertain the effect of each primitive colour, to form an accurate judgment respecting the product of the mixture.

SECTION IX.

Of the Art of Transposing, or Changing Colours.

Most colours, when transferred to stuffs, undergo or suffer some change. This art is termed, by dyers, changing, or turning the bath.

This is one of the most delicate and interesting operations connected with dyeing. In it resides nearly all the mystery of the art.

We can here only briefly sketch the principal changes, or alterations that may be produced on a colour, by the action of colourless bodies. For more particular information on the processes of dyeing, we must refer the reader to those which treat professedly on the subject.

The acid solution of tin reddens cochineal, and brightens the colour of its decoction.

Cream of tartar renders of a brighter yellow the same colouring principle.

The solution of alum changes a scarlet into a crimson. Hence it is that cloth, to which alum has been applied as a mordant, assumes a crimson colour in the scarlet bath.

The scarlet is converted by the alkalies into violet. The red of cochineal is changed by sea salt into lilac shades, which approach to a blue. Sal ammonia deepens it, without depriving it of the red. Gypsum changes the red into blue.

The red of cochineal is converted by copperas into violet. Hot water renders it blue, by impairing the vivacity of the red.

The madder red is susceptible of the same modifications, though less perceptibly. The acids render it yellow, and change it to orange. Lime, and other calcareous salts, impart to it a vinous colour.

The alkalies are employed to give a rose tint to the red of Brasil wood, and to form a false crimson upon silk. The alkalies give a yellow shade to the red of carthamus, or bastard saf-

fron. Its colour may be restored by citron or lemon juice.

The alkalies develop the colour in all vegetables employed to furnish a yellow dye. A solution of potash is even used to transfer to cotton the colouring principle of woad.

The alkalies disguise the red colour which is combined in the annotto with the yellow; the acids destroy or counteract their effect, so that by the aid of these two salts, may be communicated to the annotto all the intermediate shades of colour, from the lightest yellow to an orange.

The alkalies convert into a permanent orange the yellow procured from wool and silk by the nitric acid. For this purpose it is sufficient to pass these two stuffs, coloured by the acid, into a caustic alkali.

By employing the acid at 25, or 28 degrees, a very beautiful colour is obtained.

The alkalies are also employed to change the violet procured from Brazil and India wood; they improve the colour of the Brazil, and render brighter the violet of the logwood.

Silk prepared as for the true violet, may be

changed into purple, by means of a little arsenic introduced into the cochineal bath.

What relates to the art of changing, or transposing colours, may, in general, be reduced to very simple principles.

1. When the reds are pure, the acids render them pale, or of an orange tinge, by assimilating them to a yellow colour.

Alum, cream of tartar, the solution of tin, and acids, produce the same effect.

2. When the reds are mixed with a portion of blue, not possessing much fixity, the acids exalt the colour, by destroying or reddening the blue. Examples of this are furnished by fernambucca, and by nearly all the false vegetable reds.

3. The alkalies destroy the resinous reds, and develop the yellow which is united with them

The red tint of the annotto, as well as that of the carthamus, is effaced by them; acids restore it.

4 Alkalies restore the violet colours, reddened by acids, with greater intensity than they formerly possessed.

5. Sea salt, and all the calcareous salts, change the reds into a bluish crimson.

6. Iron, and all its combinations, impart a brown tint to red and yellow colours. Thus are produced all the different browns, which are at present so much in vogue.

SECTION X.

Of the Exaltation of Colours.

The beauty of colours depends unquestionably on making a proper choice of materials; but in the mode of combining and heightening them, consists the art of dyeing.

Washing improves the colour, by depriving the stuff of the colouring matter uncombined with it.

It ought to be performed in clear and running water.

The alkalies are employed to heighten certain colours. Thus, for example, in order to impart greater brilliancy to the Adrianople red, the cotton, after maddering, is boiled on a ley of soda, for twenty-four, or thirty-six

hours; after which it is washed and again boiled in a solution of soap.

The violet colours, transferred to cotton by the oxyd of iron and madder, are heightened and improved in a similar manner. The colour, which appears black on taking the cotton out of the bath, becomes bright, and forms a beautiful violet. It may be remarked, that the violet is changed into red by the action of alkalies, and into blue by that of soap.

The acids likewise prove useful; by putting the poppy-coloured silks through tepid water acidulated by citron juice, the colour is rendered more brilliant and pleasing to the eye. The orange extracted from annotto is heightened and improved by the citric acid.

All the acids destroy the violet colour which the cochineal sometimes assumes on wool, and exalt it to the shade of scarlet. They render the madder-red slightly yellow.

M. Hausmann proposes to pass the cottons on being taken out of the blue vat, into a water acidulated by the sulphuric acid, having ascertained that the colour was by this means rendered more intense.

Blacks, transferred into a saponaceous solu-

tion, or into water agitated for a considerable time, with a little oil, assume a deep red colour.

The drying of stuffs in the sun, or in a clear day, spoils or destroys their delicate and lively colours. Drying in the shade preserves them.

CHAPTER XXV.

Of Fermentation.

THE intestine motion which takes place in the parts of animal and vegetable bodies, under certain circumstances, is termed fermentation. By it bodies are changed, and new compounds produced.

We shall here, however, chiefly consider fermentation in so far as it furnishes products applicable to the arts. According to the nature of these products, it is divided into two kinds, the vinous and acetous fermentation.

We are indebted to M. Fabroni of Florence, for the first accurate ideas on the subject of vinous fermentation. To this able chemist was adjudged the prize by the Academy of Florence, in 1785, for his memoir on the art of making wine. This work was afterwards published by himself.

This shews that the grape is composed of

two separate substances, which can only be intimately combined by fermentation.

One of those substances is of a saccharine nature, and exists in the small cells lying between the centre and the exterior covering. The other is a vegeto-animal substance analagous to the gluten of wheat, and which is found in the membranes which divide the small cells, in which are deposited the various liquors.

M. Fabroni has ascertained that the juice of the grape deposits by rest a matter which constitutes one fifth of its bulk. He adds, that by exposing the juice to a strong heat, we may give consistency to this principle, and that thus the juice may be entirely separated from it by the filter.

He proves, that when the juice is completely deprived of this principle, it is no longer susceptible of fermentation, and that we can only restore to it the property of fermenting by redissolving in it a portion of this principle.

M. Fabroni has moreover observed, that the glutinous principle of wheat can supply the place of this sediment or the vegeto-animal gluten, of which we have spoken; he has made

the same observations respecting the juice of plants which become inspissated by heat, and on the flowers of elder which contain the same principle.

He has shewn that the frothy matter thrown up during the vinous fermentation, and the yeast from beer have the greatest affinity with this vegeto-animal matter.

M. Thenard has made similar experiments on the juice of the gooseberry, on that of cherries, and several other fruits.

Hence the fermentative principle may be regarded as a vegeto-animal substance.

From the experiments of M. Seguin it results, that a slight difference prevails between yeast and the ferment of fruits. Yeast is soluble when digested with warm water, and its solution ferments with sugar ; whereas the ferment of fruits is coagulated by heat. Hence it should seem, that albumen is either not contained in leaven, or at least in a much less quantity.

These differences of action indicate modifications in the nature of the substances, and not that they are different in themselves.

The same chemist distinguishes two states in

the vegetable albumen, the principle of fermentation; one in which it is soluble as in the juices of fruits, and the other in which the fibrous principle is developed and renders the ferment insoluble. Thus M. Berthollet has proved that boiled or desiccated yeast enters into fermentation less readily with sugar, and that gluten ferments more promptly when there has been added to it a small quantity of tartar, &c.

Hence then we may regard this vegeto-animal matter as the germ, or the principle of fermentation. When this matter is mixed with a saccharine principle, either naturally or artificially produced, fermentation takes place. There is separated much carbonic acid gas, which rises in bubbles from every part of the mass, and escapes at the surface; the liquor becomes turbid, gradually loses its saccharine qualities, and acquires a vinous odour and taste. During this process a frothy mass forms on the surface; a ropy matter is precipitated, and the liquor becomes clear; the fermentation then abates, but may be restored by agitating the liquor.

The froth and sediment are mostly composed

of the vegeto-animal part; the lees themselves are formed almost entirely of it. Rouelle obtained a considerable portion of ammonia from this last substance, and M. Proust has demonstrated that the greatest analogy exists between it and animal matters.

When vinous liquor settles or is clarified, fermentation can scarcely be produced; it may even be abated when at its height by filtering the must or wort; and again established at pleasure by re-diffusing in the liquor the ferment which remains on the filter.

From these facts M. Berthollet concludes, that the ferment is much more active when only suspended in the liquor than when dissolved in it.

From the calculations of Lavoisier on this subject we learn, than 100 parts of sugar consumed only 1-72nd of dry yeast; that it produced a little more than 35 parts of carbonic acid, and that vinous liquor gave nearly 58 of alcohol.

By an accurate attention to the phenomena exhibited during the process of vinous fermentation, we perceive the reciprocal action of two substances, the ferment and the sugar. The

first effect of this action, viz. the formation of carbonic acid, which continues to be produced till towards the end of the process, is too evident to escape notice.

The subtraction of the oxygen and carbon which is a necessary effect of the production of this acid, must render the hydrogen predominant, and the fermenting mass must reach that point when nothing remains but an inflammable liquor. This necessary effect of the fermentation is so much the more easily conceived, as sugar contains 0,64 of oxygen, according to the calculation of Lavoisier.

From the above principles it is evident that a difference of the proportions between the yeast and sugar, must produce the greatest difference in the product.

The most perfect fermentation must be produced when the proportions between these two principles are such, that at the termination of the process there remains neither sugar nor yeast.

But if either the one or the other predominate in the natural and original composition of the grape, the fermented liquor will exhibit

characters with which it is proper to be acquainted.

When the sugar is in excess, all the yeast is consumed without the liquor losing its saccharine taste, so that a portion of sugar remains dissolved in the spiritous liquor after the fermentation, and gives a saccharine taste to the mass; this is particularly observable in those wines produced from the sweetest grapes.

There is no danger of these saccharine wines becoming sour, not only because the fermentative principle is exhausted, but because the sugar acts in some measure as a condiment to the liquor.

When on the contrary the vegeto-animal part predominates, it is found necessary to stop the fermentation as soon as the sugar is consumed, as otherwise the liquor would become sour, by the action of the leven on the other substances contained in it.

It is common to stop the fermentation by decanting the clear wine from the lees, by clarifying it with isinglass, by sulphuretting it, corking with care the vessels in which it is contained, and placing them in a cool situation.

The intention of all these processes is to extract the remaining leven, to moderate its action, or to produce in it a state of coagulation, in order to diminish its effect.

The above theory respecting spirituous fermentation, naturally leads us to that of acetification, because as soon as the saccharine principle is absorbed, if any leven remains in the liquor, it unites with the other principles and produces acetic acid.

Hence it follows, that if the yeast be added in too great a proportion to a decoction of rye flour, the fermentation, after having developed the small portion of alcohol furnished by the minute quantity of sugar contained in the rye, will afterwards render the fermenting mass sour. The following experiment leaves no room for hesitation on this subject

I took a portion of rye flour, and formed it into a paste with cold water, and afterwards gradually diluted this paste with boiling water to the consistence of pulp, which felt under the spatula like syrup I carefully mingled this substance with yeast in the proportion of 2 to the 100.

The mixture soon began to swell, and dis-

engaged much carbonic acid; but at the end of a few hours its motion became lessened.

The liquor exhaled the odour of alcohol.

I then agitated the mixture, which acquired in the course of a few hours a decidedly acid character. Every day during a fortnight, the acidity augmented, particularly if care was taken frequently to shake the mixture.

The fermentation of grains differs very little from that of the juice of grapes; and in the approximation of this last we have a confirmation of the principles already mentioned.

Sugar does not exist in grain, or if it does exist, it is in too small a quantity for us to hope to obtain the products of the vinous fermentation, when it is fermented without previous germination.

Germination evolves the saccharine principle in all kinds of grains, since as M. Th. de Saussure has shewn, carbonic acid is produced during this operation, from a combination of the oxygen of the atmosphere with the carbon of the grain, so that by the subtraction of a portion of the carbon, the saccharine principle is formed.

But the decomposition of the grain ought to

be stopped when it has reached this state, if we wish to obtain true vinous fermentation; because after this first state of germination, the increase of the plant, and the ulterior decomposition of the grain, when it is not put into the earth, destroys the sugar and gives birth to other principles. Thus, in breweries, after having produced the germination of the grain by moistening it with water, its progress is stopped by exposing the grain to a heat of from between 40 and 42 degrees, until it be perfectly dry. It is then ground and all the soluble principles afterwards extracted by pouring above it warm water, at first of 40 or 45 degrees and then at 80; these different infusions are then boiled for two or three hours with hops, afterwards transfer it into a vat, and add fresh yeast in the proportion of one ounce to 160 lbs. of the infusion. It is left to ferment until it sinks down, after which it is taken out of the vat, and allowed to throw up the froth, which consists of yeast mingled with a little of the beer, highly impregnated with hops, which has no longer a sour or austere taste.

The hops answer two purposes in this ope-

ration; they prevent the developement of the acid fermentation; and communicate an agreeable flavour to the beer. We have already mentioned, under the article vinegar or acetic acid, that in order to produce good vinegar from beer, it is necessary to ferment the grain without the addition of hops.

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